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THE

TREATMENT OF WOUNDS

ITS

PRINCIPLES AND PRACTICE, GENERAL AND SPECIAL

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BY

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PREFACE.

In 1883 the author contributed to "Wood's Library of Standard Medical Authors" a volume on The Treatment of Wounds. At that time the methods of Lister had reached their highest vogue and had begun to wane, although the spray and carbolized dressings were still much in use; the profuse use of iodoform, without exact knowledge as to the real part it played as an antiseptic, was dominating many clinics, and the power of corrosive sublimate as a practical germicide was just gaining credence, and a tidal-wave of sublimate irrigations was beginning to sweep through surgical operating rooms. The observations of Ogston upon the bacteria of suppuration had just been published, but those of Passet and of Rosenbach were yet unknown.

During the period which has elapsed since the publication of that book the advances that have been made in the knowledge of the essential agents in most disturbances of wound-healing, and of the best methods of preventing or modifying the activity of these agents, and the accumulation of experience in dealing successfully with wounds of regions and organs that had hitherto been considered out of the limit of prudent interference, have been such as to make it necessary for the author practically to write a new book in an effort to present the present status of surgery in this most important department.

In the present book the plan of the former one has, however, been adhered to in its main features, as one eminently suitable for the orderly and full setting forth of the facts and doctrines belonging to the subject. In the first part the principles upon which the treatment of wounds in general should be based are discussed; then the means which are available to the surgeon for satisfying the demands of these principles are described; finally, a series of chapters are devoted to the peculiarities attaching to wounds in special regions and organs.

The mastery over the processes of repair in the human body, which

such an exposition shows to be possible for the surgeon to exercise, is full of intense interest to the student and philosopher; the demonstration of the principles and the methods whereby such mastery, in its highest degree, is to be secured is one of the achievements of the last thirty years; within the professional life, therefore, of the present generation of active surgeons has the whole development of knowledge with reference to the relations of micro-organisms to the disturbances of wound-healing taken place, so that they have been active participants in the practical application of every step of the gradually developing antiseptic and aseptic methods of wound-treatment, from the first crude local applications of carbolic acid to destroy the results of infection in wounds, described by Mr. Lister in 1867, to the minute and elaborate technique for the prevention of infection which characterizes the surgical work of 1898.

The stage of novelty and of disputatious discussion as to the fundamental facts of the new surgery has passed. The chief interest of to-day gathers about questions of how to most perfectly bring practice into accord with knowledge, so as to secure the best attainable results in the ever varying and widely differing conditions in which wounds present themselves for treatment. The aim of the present volume is to concisely present means and methods that shall secure such results.

LEWIS S. PILCHER.

386 Grand Avenue, Brooklyn, N. Y.
November 1, 1898.

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THE PRINCIPLES OF WOUND TREATMENT.

THE

TREATMENT OF WOUNDS.

CHAPTER I.

GENERAL CONSIDERATIONS ON WOUNDS.

Importance of Wound-Treatment—Modern Methods of Surgical Study—Principles of Wound-Treatment Analyzed—Definitions—Classification—Influences that Modify the Healing of Wounds.

"THE treatment of wounds is undoubtedly not merely the first stone, but also the corner-stone of surgery. By it surgery has attained its greatest triumphs; by it our branch of the profession has conferred its greatest benefits on mankind; by it each individual surgeon may hope to do more good than in any other way. Nevertheless it has ever been one of the opprobria of surgery; though it was the first work in which surgeons were engaged, it is at the present day one of the chief questions of surgery, and I trust it will remain so till it has attained to perfection."

These words by Professor George M. Humphrey, in the Surgical Section of the International Medical Congress of London, in 1881, do not too strongly set forth the importance of the subject of the treatment of wounds. It has been too much considered the highest exercise of the skill of the surgeon to make wounds, and the deftness and neatness, perhaps the brilliancy, with which the mere mechanical portions of the surgeon's work may be done have been considered as more important evidence of merit than the less striking and more prolonged duties required in the after-treatment, in the course of which his judgment and the resources of his science are continually being put to their highest test. Not only is

this due in great measure to the fact that the awe and admiration with which the laity look upon the deliberate wounds which are made by a surgeon, clothe such procedures with undue importance; but it is also fostered by the improper methods of surgical instruction, so long pursued, in which the chief interest is made to centre upon the operative procedures, and little or no attention is directed to the details of dressing and after-treatment.

It may be considered as one of the best evidences of the solid character of the advancement which is claimed for the surgery of to-day, that in its discussions and in its practice the principles of wound-treatment have attained an overshadowing importance, while the mechanical details of operative surgery have been relegated to a minor place.

That which has contributed to this end most especially is the application to surgery of the rigid experimental methods of investigation of modern Science, by which general impressions, formed from imperfectly noted or understood experience, have been substituted by exact demonstrations, guarded by adequate checks and careful precautions, that serve also to emphasize the limitations and variations in the applications of the principles which they demonstrate.

While surgery has thus always been a noble art, it may therefore now begin to claim, for the first time with some justice, that it is a noble science.

During the lifetime of the present generation of surgeons such exact knowledge has been arrived at with regard to the processes of tissue repair and the sources of wound-disturbance and the methods of overcoming or preventing such disturbance that a sure basis has been established upon which to build rational and reliable methods of wound-treatment. Just in measure as this clear and indisputable establishment of these fundamental facts has been accomplished has the treatment of wounds become emancipated from theory and prejudice, and become established upon a final and perfect basis. The varying conditions that attend wounds, conditions of constitution, of environment, of structure wounded, of agent and manner of wound, the presence or absence of needed material for treatment, and the measure of perfection in the care which may possibly be given to the wound will ever be the unknown and variable quantities that will test the judgment and skill of the surgeon in the application of principles to practice.

The *principles of wound treatment,* then, are of the highest importance as preliminary to the adoption of rational methods of practice, and by their study only can any steady and permanent advance in wound therapeutics be made.

In recognition of this, in the discussion of the treatment of wounds to which the present work is devoted, there will first be considered the principles upon which treatment should be founded, and from this it will be possible to proceed to the application of these principles in the choice of methods to be adopted in practice. The plan of such a study will include:

First.—The immediate effects of a wound upon living tissues.

Second.—The processes instituted by nature, when undisturbed, for the repair of the injury.

Third.—Possible sources of disturbance, and their effects upon the natural reparative processes.

Fourth.—The means by which the natural reparative processes may be most effectually favored and the action of disturbing agents may be minified.

Before proceeding with this study, certain further general considerations should be noticed. These include matters of definition, of classification, and of the modifying influences of a general character that affect the repair of wounds.

DEFINITIONS.—A wound is a division of continuity of the bodily texture, produced, either directly or indirectly, by sudden mechanical force. Wiseman, "the Father of English surgery," limits the use of the term wound to injuries involving division of the skin. In his "Chirurgicall Treatises" (1676), p. 331, he thus discourses: "A wound is a Solution of continuity in any Part of the body suddenly made, by anything that cuts or tears, with a division of the Skin. This *Definition* differs much from what is usually delivered by Authors; and it is fit it should. For they generally defining a Wound by a Solution *in parte molli,* do thereby exclude a Cut made into a Bone, as that into the *Cranium* by a Pole-axe, etc., which why it should not be called a Wound I know not. I say, it is *made by anything that cuts or tears.* Other Authors define it to be made by an external Instrument, etc. How then do they call that *fracturam cum vulnere,* a Fracture with a Wound, where the Bone from within

makes the Wound, and thrusts itself quite through the Flesh. *Sennertus* adds to his definition, that it is to be done *à re secante* and *acuta:* yet he reckons those for Wounds that are made by Bullets, although it be a Cannon-shot. I do therefore think it fit to make my Definition more comprehensive, and to take in whatsoever makes a sudden Solution of continuity, at least immediately and by itself, on what Part soever it lighteth. So a Cut into a Bone is a Wound. Tearing the Flesh, Nerve, Sinew, Tendon, or Cartilage, by Bullet, Stone, Splinter, etc., is a Wound. Only I add this restriction, that *the Skin must be* likewise *divided:* by which last words I exclude Fractures that come not through the Skin, and Contusions if the exterior parts be continuous. But by the word *Skin* I understand not only the external *Cutis,* but also the inward membranes of the Gullet, Ventricle, Guts, Bladder, *Urethra,* and Womb; all which are capable of Wounds from Sharp Instruments, either swallowed or thrust into them."

Though the practical importance of the separate classification as made by this classical author, of injuries involving division of the skin or mucous membrane is still recognized, yet to make this an important element in a general definition is arbitrary and artificial.

The occurrence of a solution of continuity in any of the solid tissues of the body may be due to slowly acting causes, as the gradual waste of atrophy or the more active disintegration of ulceration, but a breach of tissue thus affected would not be a wound. There is involved in the idea the action of a force outside of the tissue itself, which by mechanical force has rent or divided its substance. Even in those cases in which so-called spontaneous rupture of muscular tissue occurs, it is not the contraction of the tissues alone that is the cause of the rupture, but the force opposed to it exerted through the bony levers into which it is inserted.

The term wound, therefore, is susceptible of a very wide range of application. Contusions, sprains, fractures, subcutaneous as well as cutaneous breaches of tissue are included in the term. In all essential particulars they will be found to be identical accidents, involving the same methods of repair and subject to the same principles of treatment, their apparent differences depending upon accidental differences of function, nutrition, relation to other parts, extent of traumatism suffered, and of exposure to disturbing influences from without.

These accidental differences are especially marked in the conditions which those wounds of bones that constitute fractures present. Though the method of repair and the principles involved in treatment are the same in these wounds as in those of the soft parts, yet the application of these principles in the varied fractures of the bones of the skeleton involves so much of detail that, by common consent, these wounds have been classified apart. In accordance with this general usage, which is of practical importance, the systematic consideration of fractures of individual bones will be excluded from the plan of the present treatise, in which attention can be given only to considerations pertaining to osseous injuries in general.

CLASSIFICATION.—The first great division of wounds is into *subcutaneous* and *open* wounds, the division depending upon their relation to the common covering of the body. Subcutaneous wounds include all which are unaccompanied by breach of the skin. Protected by the unbroken skin from external irritation and infection, their repair is usually rapid and undisturbed by untoward complications.

Open wounds, as a class, include all which exhibit a breach of the skin, or mucous membrane. They may present the widest extremes of tissue-breach, and of loss of substance. Those of this class, whose exposed surfaces may be quickly brought and kept in apposition, differ but little in their gravity from subcutaneous wounds. Failure to secure such apposition, whether by intention or from necessity, so modifies the course and duration of the process of healing, and so exposes the wound to dangers of disturbance from without, that such wounds constitute a well-marked class by themselves. To characterize this class only, the term open wound is most commonly employed.

Wounds are again divided, from the character of the agent or force by which they are produced, into *incised, punctured, contused, lacerated, gunshot,* and *poisoned* wounds, according as the wounding agent has been a sharp cutting edge, a penetrating point, a dull and bruising body, a tearing force, a projectile impelled by the force of exploding gunpowder, or one which carries with it into the wound a poison. These divisions, with the exception of the last, are indefinite general ones for convenience of description. They are all alike in kind, and differ only in the degree of the injury sustained. Whatever force or agent produces a breach of

tissue, occasions likewise death of tissue in the track of the breach. The sharpest and most delicate cutting edge, when viewed through a lens of sufficient magnifying power, is seen to be rough and saw-like. Though the extent of the destructive action of an instrument is lessened according to the fineness of the edge, yet the track of the keenest edge through a tissue is lined by disorganized particles that have been killed by its impact. Between a slight and clean incised wound, in which the destruction of tissue is limited to the molecules traversed by the cutting instrument, and an extensive lacerated wound with roughly torn and contused edges, or between a slight bruise and a contusion producing the death and disorganization of large masses of tissue, the difference is one of degree, and not of kind. In the slight as well as in the severe injury there is dead tissue that must be taken care of.

The important practical difference which has always been recognized in the healing of incised and punctured wounds, as compared with contused and lacerated wounds, has given importance to these distinctions as a basis for a clinical classification. These differences, however, depend simply upon the difference in the facility with which the devitalized tissue is prevented from becoming a source of disturbance to the healing of the wound in the several instances.

The class of *poisoned wounds* embraces a much wider range of injuries than its traditional application was intended to comprehend, and the most important practical classification of wounds is based upon the presence or absence of poisonous substances from a wound. Any substance is a poison which, in addition to the immediate gross chemical or mechanical effects which it may produce, displays a specific subtle quality by which the vitality of the tissues with which it comes in contact is degraded, a quality which is shown by the production of disturbances of the vital processes of an intensity out of all proportion to the immediate injury that may have been inflicted.

Decomposing animal matter, certain secretions of particular animals, conveyed by their bites or stings, and certain vegetable juices, when introduced into wounds, are followed by disturbances in their repair so marked that their separate classification as poisoned wounds has been natural. The uncomplicated effects produced by any traumatism have been long studied in subcutaneous injuries, in the repair of which, even

when involving much contusion and laceration of soft parts and extensive effusion of blood, as a rule, sloughing, suppuration, and inflammation do not take place, but the effused liquids and the devitalized tissues are removed by absorption in due time, and no disturbance beyond that inflicted by the original wounding agent is experienced. Similar wounds, to which access of extraneous matter is permitted by reason of a breach in the skin, invariably have their repair disturbed by putrefaction and sloughing of the devitalized tissues, by decomposition and liquefaction of the blood-clots, by inflammation of the wound margins, and by a prolonged process of suppuration and granulation in the healing of the wound. Such results, however, do not take place when the articles allowed access to a wound are purified of organic particles which are capable of inducing putrefaction in animal matter. Such wounds, though open and containing contused and devitalized tissues and blood-clots, pursue the same course of repair as do subcutaneous wounds. Whenever, therefore, inflammatory, suppurative, and sloughing conditions arise in an exposed wound it is the result of the introduction into it of foreign matters, which act as poisons in the disturbances of the reparative processes that they create. The term poisoned wounds is thus made to extend in its application to the great mass of open wounds, those to which it was originally applied being simply examples of inoculation with special poisons. Upon this fact of the presence or absence in a wound of poisonous foreign material a classification of the greatest practical importance is possible, viz., into *aseptic* and *septic* wounds.

Aseptic wounds include all which are preserved from contamination by poisonous materials, whether such poison be applied directly to it, or be generated in it by the action of germs that gain access to it and find within it the conditions favorable for their growth. An aseptic condition in a wound may be obtained either by the protection which the wound receives from the first against the access of any septic agent, or by the power of living tissues to resist and destroy septic agents, or by the application to the wound of substances which destroy them. Examples of the first class are presented in subcutaneous wounds, and in operative wounds which are inflicted with certain precautions; examples of the second class are seen in all open wounds in which union by first intention is secured, notwithstanding at the time of their infliction they were freely

exposed to ordinary air; examples of the third class are presented by wounds in which the application of antiseptic substances has been successful in arresting the action of whatever septic agents may have previously gained access to them. Asepsis in a wound is of the highest practical importance. As long as it is maintained no decomposition of the secretions of the wound takes place, no sloughing of killed or partly killed tissue occurs. When the proper cares to favor the nutrition of the wounded tissues are rendered, the healing of the wound progresses without pain, inflammation, or suppuration, and the least possible amount of cicatricial tissue is produced. To secure an aseptic condition in a wound, or to approach it as nearly as possible, is the first and most important indication in wound-treatment.

Septic wounds include all in which any agent capable of exciting tissue irritation and cell necrosis lodges and grows. They may present the most widely different degrees of wound-disturbances dependent upon the varying conditions which the special wound may present, and upon the character of the treatment which is instituted, but in all cases they are attended with some degree of inflammation and suppuration, and with sloughing of dead tissue. The septic agent may be introduced by the body that inflicts the wound, or by the dressings that are applied, or may be among the dust particles that float in the air to which it is exposed. In very rare instances, also, it is possible that it may be conveyed to the wound through the blood of the wounded person himself.

Modifying Influences.—The effects in individual cases which particular injuries produce are never the same, and may widely differ. They are modified by *idiosyncrasy, mental state, age, previous constitutional condition, disease,* and *hygienic conditions.*

Differences as to the ability to bear injuries exist among races, nations, families, and individuals. The Latin races have less resisting power than the German and Anglo-Saxon. Oriental nations surpass the Occidental in their tolerance of injuries. Of individuals of apparently good physique, and enjoying the same hygienic surroundings and treatment, one will recover from the most serious injury speedily and without serious complication, while in the other an injury, apparently much less severe, may end fatally or in prolonged illness.

The power of resisting the effects of extraneous influences to some

degree is a characteristic of all living matter. Its cessation is death, and a dead tissue and a passive tissue are synonymous. The quality of the vital resisting power inherent in the constitution of an individual cannot be estimated by any known signs. It may be modified by other conditions, but in some degree it is always present as a powerful unknown factor influencing the result of any case. It is a measure of the vital force of the particular individual, and is what is meant by the term idiosyncrasy as here used.

Mental states may modify greatly the effects of injuries. The shock which attends the reception of an injury is particularly closely associated with mental conditions. The mere apprehension of injury has been known to produce death through shock, and the ability to rally from the physical impression made by an injury is modified by the state of mind of the injured person. The reparative processes likewise are subject to the influence of mental conditions. They are promoted by the emotions of hope, joy, expectation, confidence, and resignation, and may be hindered by fear, anxiety, disappointment, and allied states. This is illustrated on a large scale by the difference which has been remarked in the repair of wounds which have been sustained by a victorious army and those by a defeated and dispirited one.[1] In general, it is important to remember that, as it is expressed by Tuke,[2] "The influence of the mind upon the body is no transient power; in health it may exalt the sensory functions or suspend them altogether; excite the nervous system so as to cause the various forms of convulsive action of the voluntary muscles, or

[1] "The influence of the mental condition on the results of wounds is undeniable. All reports agree that the wounded of victorious troops, elated by the successes achieved by their own bravery and that of their comrades, did better than those of defeated armies. The most striking example of this influence of the mental condition in the successful treatment of wounds in modern times is the fearful mortality among the French, after shot wounds of all kinds, in the war of 1870-71. The excessive mortality of that campaign was undoubtedly largely owing to the mental depression caused by a succession of reverses rarely met with in the history of warfare" (Medical and Surgical History of the War of the Rebellion, Part Third, Surgical Volume, page 868).

[2] D. H. Tuke: Influence of the Mind on the Body.

depress it so as to render them powerless; may stimulate or paralyze the muscles of organic life, and the processes of nutrition and secretion—causing even death; that in disease it may restore the functions which it takes away in health, reinnervating the sensory and motor nerves, exciting healthy vascularity and nervous power, and assisting the *vis medicatrix naturæ* to throw off diseased action or absorb morbid deposits."

The influence of age in modifying the effects of wounds is exerted in a threefold way. At the two extremes of life the immediate shock from injuries is more liable to be serious, but in the young it is more quickly and completely rallied from, while in the old its development may be more slow in its manifestation and ultimately overwhelming in its effects. Secondly, the reparative power is greater in all parts of the young than in those of the older individuals of all species. The activity of nutrition in youth favors repair after injury; the effects of this favorable influence are notable in the difference between the readiness and completeness of repair in children and that in adults. Lastly, the freedom from pre-existing organic disease in early life prevents complications, which become more frequent as age advances. As the result of these various conditions, the general rule may be said to be that, after the age of thirty years, the ability to resist injury decreases steadily with the increase of years.

In connection with the influence of age upon the results of wounds, it may be well to recall the experience of Paget, as given in a clinical lecture on "The Various Risks of Operations."[1] He says: "We have a large number of printing offices in the neighborhood of the hospital, and every office employs many boys from twelve to sixteen years old; and hardly a week passes but we have one or more of these boys brought in crushed by the printing-machines. Fingers, hands, and arms are thus mutilated; and I know of no class of patients that recover more remarkably. Not only they do not die, but their wounds heal steadily and quickly; they escape erysipelas and spreading suppurations and secondary hæmorrhages; and often, when, to save any piece of a hand, we leave bits of skin that seem as if they could not live, they yet do live and grow good scars." Again, referring to those advanced in life, he continues: "All

[1] Clinical Lectures and Essays by Sir James Paget, Bart., edited by Howard Marsh, F.R.C.S. London, 1875.

the risks of doing badly are at their maximum in some among the old ; but these are some of the risks for which they will always need your especial care. The old are, much more than others, liable to die of shock, or of mere exhaustion within a few days after the operation. They bear badly large losses of blood, long exposure to cold, sudden lowering of temperature, loss of food. Large wounds heal in them lazily, and hence a prolonged liability to secondary hæmorrhage and other mischiefs of open wounds. Their convalescence is often prolonged, and you may expect to meet sometimes with great disappointment in having your old patients die with some slight casual disease, as if exhausted by the long expense of vital power in healing large wounds. They get all but well, and then, after seeming for some time stationary, they fade and waste and die."

Under the head of "Constitutional Conditions" are to be classed certain general states of the blood, or of the nerves, or of the general nutrition, in which, while there is not a recognizable disease, there is still a departure from a perfect standard of health. It is rare, if ever, that any individual would satisfy the strict requirements of a perfect standard, and the varying degree and combinations of departures from this standard which different individuals present mark the constitutional differences of individuals. It differs from what I have termed idiosyncrasy in that it is a measure of the extent to which vitality has been sapped in the tissues of an individual, while the former refers to the vigor with which the tissues are able to resist deteriorating influences. Plethora, anæmia, obesity, these are gross examples of constitutional differences. I am inclined to class here also the peculiar vulnerability of tissue which constitutes the scrofulous diathesis. The conditions which result from addiction to alcoholic stimulants and to gluttony; from the exhaustion of overwork, underfeeding, or mental strain; from vicious habits, and from habitual inhalation of vitiated air; these are some of the more marked examples of influences which, by their effect upon bodily nutrition in general, aggravate the effects of injuries by prolonging the period of their repair, and rendering them more easily affected by extraneous disturbing influences.

Closely allied to the conditions just remarked upon are well-marked diseased states, such as syphilis, tuberculosis, malaria, diabetes mellitus,

and scurvy, which, by the nutritive defects which they determine, delay repair, often arrest it, and subject wounds to the most serious complications. The pre-existence of pyæmia, septicæmia, erysipelas, phlebitis, or any diffuse inflammation, will add special dangers to any superadded traumatism. Diseases of the various organs of the body, and particularly cardiac, pulmonary, hepatic, and renal diseases, modify the effects of wounds both directly, by the constitutional states which they create that interfere with repair and diminish the resisting power of the tissues in general, and indirectly, by the reaction of the injury upon the pre-existing affection, producing in it temporary exacerbation, or permanent and progressive aggravation, with not infrequently speedy death.

By their relation to the functions of nutrition in general hygienic conditions also exert an important modifying influence on the healing of wounds. Food, insufficient in quantity or bad in quality, extremes of temperature, absence of sunlight, depressing climatic conditions, lack of exercise, insufficient and impure air—these not only create previous constitutional conditions unfavorable to repair, but, when continued after the reception of a wound, directly diminish its activity. Erichsen,[1] in discussing diet after operations, remarks: "The soldier or the sailor on active service is often exposed to serious injuries that necessitate the more important operations at a time when his constitutional powers have already been broken down by scurvy, dysentery, or some other similar affection, resulting as much from the deficient quantity as from the unwholesome character of the food with which alone he can be supplied. And after the operation his only available nutriment may be of the coarsest character, possibly salted, and imperfectly cooked. In such circumstances operation-wounds do not heal, or they assume a peculiar gangrenous character; or the patient sinks from ulceration of the intestinal mucous membrane. The mortality of operations becomes enormously increased ; and there can be but little doubt that thousands of deaths which have occurred in wars between the most civilized nations and the best appointed armies may be attributed to these causes." The important influence which diet may exert upon repair should not be overlooked in the treatment of wounds. An ample supply of food, in a digestible

[1] Science and Art of Surgery, vol. i., p. 31. Philadelphia, 1878.

form, with care observed that the digestive powers of the patient should not be overtaxed, with due regard to the personal tastes and instincts of the patient, will form the general rule to be followed. The weather, in which are included temperature, humidity, atmospheric pressure and movement, may also depress or stimulate the general nutrition, and thus influence the repair of wounds. Moderately warm weather, if it be not sultry and oppressive, favors repair directly, and also indirectly by encouraging the opening of doors and windows and thus permitting free air supply. A dry, clear atmosphere is exhilarating; a damp, raw one, depressing. Dr. Addinell Hewson,[1] from a comparison of the meteorological records and the records of operations performed in the Pennsylvania Hospital during a period of thirty years, found that with an ascending barometer the mortality of operations was a little less than eleven per cent., with a stationary barometer more than twenty per cent., and with a descending barometer more than twenty-eight per cent. The frequency and mortality of pyæmia bore a direct relation to low barometrical pressure and moisture of air, while the deaths from shock occurred in a constant ratio with the opposite condition, dryness of weather.

Wales, in his work on "Surgical Operations and Appliances" (p. 124), speaking of the observations of surgeons in hot climates, that wounds heal more quickly under an elevated temperature than the reverse, says: "This is strikingly illustrated in the influence of our high summer heats over the adhesive process, which takes place much more surely than in cold weather and damp, cool latitudes. The same thing is observed in the constitution of the Arab, whose climate, active habits, and diet produce a spare and sinewy frame and a sort of dry temperament very favorable for the quick healing of wounds. I have made the same observation in some parts of the East Indies, where the population is under analogous influences. In the Gulf of Mexico the heat during the summer is excessive; and it was during a period of this sort of weather that I received into the hospital under my charge, at the mouth of the Mississippi River, a large number of the wounded during the naval operations against New Orleans. Though the buildings were crowded with the wounded and fever patients, all of the wounds healed with un-

[1] Pennsylvania Hospital Reports, 1869.

usual rapidity; and of fifteen cases of amputation of the thigh and arm but two died, both of them after secondary operations, one of the patients having lost a good deal of blood from having his knee shattered by a rifle-shot; in the other case disarticulation was performed at the shoulder for a gun-shot wound of both the axillary artery and vein." Rochard, in speaking of the healing of wounds in hot climates, says: "All of our confrères point out the rapidity of their course and the promptitude with which they heal. I have myself been able to verify it often in Madagascar. The bad guns of which the Sacolares made use often burst in their hands, and I have seen some of these complicated wounds, for which I had proposed amputation, heal with a wonderful facility, in spite of the most irrational treatment. Intertropical climates are favorable to the efforts of conservative surgery; and operations, when it is impossible to avoid them, succeed better there than in Europe. The same observation has been made in Oceanica, on the coast of Africa, in South America, and in the Antilles. It explains the almost constant success of the amputations of naval surgeons in equatorial stations, and the remarkable cures that they often obtain when it is possible to abstain from them."

The stimulating effects of sunlight upon nutrition should also be regarded in the hygienic management of the wounded. Next to the necessity of fresh air supply, that of sunlight has assumed importance in the present prevailing views as to the arrangement of hospital wards. There is an instinctive craving for the light innate in all living beings, which becomes more marked whenever, for any reason, there is a depression of vital power. Both pathetic and truthful is the observation of Florence Nightingale, in her "Notes on Nursing," that "it is curious to observe how almost all patients lie with their faces turned to the light, exactly as plants make their way toward the light. A patient will complain that it gives him pain lying on that side. 'Then why *do* you lie on that side?' He does not know, but we do. It is because it is the side toward the window." The effects of sunlight upon nutrition and growth have an excellent illustration in the hygiene of the growing child. The special application of this illustration to the course of wounds in adults depends upon the fact that in the repair of all wounds there is a return of the local tissues engaged in the repair to that condition which marks the tissues in general of the growing child.

Insufficient air is synonymous with impure air, for the purest air, if not renewed with sufficient frequency, becomes speedily poisoned by the exhalations from the persons of those breathing it. This, which is true in health, is still more quickly accomplished when the bodily exhalations are rendered more offensive by disease. It becomes therefore more important for the well-doing of the sick than it is for the welfare of the well that an unlimited supply of pure air should be provided. When to the natural sources of air-contamination there are added the emanations of suppurating wounds, the need of constant change in the surrounding air is more emphatic still, if its purity is to be preserved. While much attention has been directed to the importance of the adequate ventilation of hospitals, in the wards of which numbers of wounds are assembled, it should not be forgotten that the same necessity exists for isolated cases in their own homes, that they do not become sources of infection to themselves. Absolutely pure air is not obtainable in the ordinary conditions of life. While it is the great oxygen-carrier for the needs of the living body, it receives in exchange from the body the débris of its disintegration. It is the vehicle of transportation of an infinite variety of floating matter, the great mass of which is organic in character. Putrescible organic matter cannot long be exposed to the air without becoming the recipient of putrefactive germs from it. Aseptic wounded surfaces quickly become septic when exposed to it by reason of the floating septic particles that it conveys. The best stimulant to the vital resisting power of a living tissue, by which the effects of sepsis are antagonized and overcome, is perfectly oxygenized blood. The air thus carries both the bane and the antidote. The practical end therefore to be aimed at, in any given air-supply, is that there shall be as small a proportion of the bane and as large a proportion of the antidote as possible. This involves the removal, the suppression, or the diffusion, as much as possible, of all sources of contamination, and the dilution of that which is unavoidable by the introduction of the largest quantity practicable of the purest air attainable. The purity and the sufficiency of the air are thus seen to have a double relation to the healing of wounds, one a general relation, which the air shares with other hygienic conditions, and the other a special relation as a carrier of and an antidote to sepsis. This latter relation demands further notice. As the sources of infection are multi-

plied and brought near to wounds capable of becoming infected, will the action of the air as a medium of infection be exemplified in its highest degree. This is accomplished by the accumulation of numbers of septic wounds in one building with limited ventilation capacity. Says Erichsen,[1] "The overcrowding of wounded people, whether the wounds be accidental or surgical, will inevitably produce one of the four septic diseases, phagedæna, septicæmia, pyæmia, or erysipelas. When the word *'overcrowding* is used in connection with surgical hygiene, it does not mean the heaping together of the sick and wounded in one building beyond what it is intended to hold; but it means the accumulation in one ward or under one roof of a greater number of patients than is compatible with such purity of air as to render the septic poison incapable of development or of propagation in it."

The value of air as an antiseptic agent is shown by the diminished prevalence of septic diseases when those who, by reason of open wounds, are favorable subjects for their development, are isolated from each other and are supplied with abundance of comparatively pure air. Still the air, however great its quantity, does not destroy the particles of infection that it dilutes. It acts only by increasing the resisting power of the tissues and by lessening the amount of the infective material deposited at any one time. It is the presence of these infective particles that make it important that to a person suffering from an open wound an amount of air should be supplied in excess of that required for the ordinary purposes of healthy life. Whatever means then may diminish the number or activity of the agents of infection will by that much reduce the importance of an unusual air-supply in the treatment of wounds.

In concluding these paragraphs on the general modifying conditions that influence the course of wounds, I remark that their pertinency depends upon the truth that the treatment of a wound involves the treatment not only of the particular breach of continuity, but also of the wounded person as a whole. It is possible that in the special direction of attention to the details of local treatment matters concerning the general state of the patient may be overlooked or slighted. Too often, perhaps, this is the case. The duty of the surgeon extends, however, beyond

[1] Science and Art of Surgery, vol. i., p. 33. Philadelphia, 1878.

the restricted field of binding up the wound and keeping it free from irritation. His ministry to the mental state of the wounded may be of the utmost importance. The ability to excite in the minds of those subject to his care a feeling akin to that of the beleagured garrison of Metz toward Paré, who cried out upon his arrival among them, "We have no longer any fear of dying, even if we should be wounded; Paré, our friend, is among us," may make the difference between life and death. The special risks from age, from the previous constitutional condition, or diseases of the injured, must be appreciated and met, and the hygienic conditions in which the wounded man is placed must be made as good as possible, before the whole duty of a surgeon is accomplished.

CHAPTER II.

THE IMMEDIATE EFFECTS OF WOUNDS IN GENERAL—THE REPAIR OF WOUNDS—INFLAMMATION.

Constitutional Effects—Shock—Reaction—Traumatic Fever—*Local Effects*—Impairment of Function—Gaping—Pain—Hæmorrhage—Active Hyperæmia—*Union of Wounds* — Exudation — Vascularization — Connective-tissue Transformation—Cicatrization—Union by First Intention—Causes of Modified Repair—*Defects of Apposition—Defects of Protection—Defects of Nutrition—Modified Normal Repair*—Healing by Granulation—Healing by Secondary Adhesion—Healing by Scabbing—Suppuration—Disposition of Effused Blood and Dead Tissue—*Destructive Disturbances of Repair*—Inflammation—Infectious Wound-Diseases.

THE immediate effects of a wound are twofold in character, *constitutional* and *local*.

CONSTITUTIONAL EFFECTS.—All wounds, of every degree, produce at first a depressing effect upon the whole body. This is accomplished through the nervous system, may be so slight and transitory as to be unnoticed, or may be so profound as to cause instant death. This general depression constitutes *shock*. It manifests itself most prominently through the circulation by diminution in the contractile force of the heart and arteries—reflex vaso-motor paralysis. The varying degrees of depression of nerve-force and of heart-failure which may be produced by the infliction of a wound cause the symptoms of shock to vary from momentary pallor and mental confusion to a condition of profound prostration. When the vital powers rally from this state of depression and the different organs begin to resume their proper functions *reaction* is said to have taken place. In the most favorable cases reaction is gradual and progressive, though it may occupy many hours, or even days, in its course. Returning color to the face and increased power in the heart's action are its earliest signs. In certain cases fluctuations in the reaction occur, relapse alternating with improvement for a variable time. In some cases

there is an imperfect reaction, characterized by rapid and weak heart's action, cerebral excitement, muscular tremor, and high body temperature. The result of such a condition is doubtful, speedy death or ultimate recovery after a prolonged struggle being possible.

The reaction from shock is commonly attended with elevation of the body temperature, quickening of the pulse, thirst, derangement of the secretions, restlessness, and headache. This fever of reaction may be so trifling and evanescent as to escape notice; its grade of severity depends chiefly upon the nervous excitability of the patient, his previous constitutional condition, and the amount of local irritation produced by the injury. Children manifest it most readily. It is of reflex nervous origin, makes its appearance usually within a few hours after the reception of an injury, and may be expected to decline on or after the second day. Its most severe manifestations are seen in cases of imperfect reaction, its combination with which produces the condition of excitement with prostration which characterizes these cases. It may be dangerously intense, and is then apt to be accompanied by a delirium, which is generally wild in character but temporary in duration, subsiding with the restoration of the general bodily functions. This reactive fever is to be distinguished from the fever which complicates the repair of injuries, which does not develop until two or three days after an injury, and is dependent upon general blood-infection by absorption of septic matters from the injured part. The two might very properly be designated as *primary* and *secondary traumatic fever.* The secondary is often engrafted upon the primary.

Local Effects.—All breaches of tissue are produced either by a force of traction, tearing asunder the elements from each other, or by direct pressure forcing the elements asunder. The first constitutes a *laceration,* the second a *contusion.* When a laceration is inflicted a greater amount of damage is likely to have been done than the particular breach would indicate, owing to the wide distribution of the effects of the strain, the culmination of which at the point of rupture alone is declared by the wound. The strains, rents, and ruptures of ligaments and capsules that result from joint-wrenches, distortions, or dislocations, muscular ruptures, the sprains of tendons and tendon-sheaths occasioned often in violent manual efforts, the tearing away of epiphyses and bony

prominences through strain upon the muscles or ligaments attached to them, and rents in the substance of internal organs, or their separation from their connections by the jar of falls, are examples of subcutaneous lacerations. By the prolonged impairment of function which they produce they illustrate the force of the statement as to the wide distribution of the effects of strain. A contusing force may likewise act as a lacerating force upon the tissues beyond the range of its direct impact, and the most severe wounds, as regards the difficulties which attend their treatment, are those in which laceration and contusion are combined, as in the accidents produced from the entanglements of limbs in machinery or by their crushing under moving wheels. In a pure contusion, however—that is, a breach produced by direct pressure only—the traumatism is limited in its extent by the area of the impact, but the crushing of the tissues may be of any grade, from the imperceptible molecular divisions of a clean incision or a slight bruise to the pulpification of large masses of tissue.

The local effects of a wound, however produced, may be classified under the five divisions of: 1, *Impairment of Function;* 2, *Gaping;* 3, *Pain;* 4, *Hæmorrhage;* 5, *Active Hyperæmia.* Of these the four first need receive here but brief mention. The last will exact more consideration, as it is the initial condition upon which is built up the consequent repair of the wound.

Impairment of function is the necessary and immediate result of tissue-breach. Its character is determined, in a particular wound, by the varying functions and relations of the tissues that have been severed. Its extent and duration will depend upon the amount of injury, the activity and regularity of the processes of repair, the perfection of repair of which the tissue is susceptible, and the amount of new material needed to fill up any gap between the divided tissues that may have resulted from loss of substance or gaping.

Gaping depends upon the contractility of the tissues and is due to the destruction, by the solution of continuity of the tissue, of the natural force by which they are kept extended. It becomes important when the wound is transverse to the direction of the principal fibres of an organ. Tissues in a state of tension, tissues in whose structure there is much elastic tissue, as the skin and arteries, and tissue that has the power of

contracting, as muscular tissue, when wounded, exhibit gaping in the most marked degree.

Pain results from the impression made upon the sensory nerves of the part, and hences varies with the nerve-supply of the parts. The temperament, likewise, of the individual modifies the amount of pain experienced. Mental preoccupation or excitement often prevents the perception of pain. Great rapidity in the infliction of a wound diminishes the pain resulting. Extensive operations with the assistance of the "surgical engine," by which the instruments used are made to revolve with inconceivable rapidity, may be done with little or no pain. A temporary benumbing of the parts is produced when the injury is instantaneously inflicted. Subsequent sensation is one of smarting or burning. This is experienced in all wounds, and is of short duration.

FIG. 1.—Section through skin of guinea pig eight hours after a wound: *a*, the wound, filled with clot, the capillaries thrombosed on both sides; round-cell infiltration; *b c*, sweat gland; *d*, hair follicle.—*Shakespeare.*

The amount of hæmorrhage which is provoked by a wound depends upon the number, size, and character of the wounded vessels, and the conditions which either the situation of the wound itself or the art of the surgeon applies to arrest it. The natural hæmostatic is the coagulation of the blood, which spontaneously seals up the divided extremities of the capillaries and smaller vessels, filling them with a thrombus as far as to the next branches of the vascular network. In open wounds the effused blood, in great part, either spontaneously flows away or may be wiped away; a slight layer of coagulated blood, however, remains, with rare exceptions, in the interstices of the wound surfaces (Figure 1). In subcutaneous wounds the character of the tissue in which the vessels lie influences also the extent of blood-effusion. Loose connective tissue favors

extensive and rapid infiltration. The escape of blood into the cavities of the body may be a dangerous complication both by reason of the possible amount of the hæmorrhage, and from the pressure which it may exert upon important organs. Blood-clot may interfere with repair, either mechanically, by preventing apposition of the wound-surfaces and maintaining a gap to be slowly filled up by new tissue, or by affording a favorable substance for the lodgment and development of septic matter from without.

The parts immediately adjacent to a wound speedily swell somewhat, and by their increased redness show some capillary turgescence. From the dilated capillaries an amount of plasma is exuded in excess of the normal, which infiltrates the tissues adjacent to the wound and appears as a more or less copious effusion—wound-secretion—upon the free surface of the wound when accurate apposition is not maintained. The amount of this capillary dilatation and of the consequent effusion and swelling can be greatly restricted by shielding the wound from further irritation, keeping the parts at perfect rest, and subjecting them to equable and gentle compression. A certain amount of capillary distention in the wound-flaps may be passive, the result of the closure of a part of the blood-paths, by which a less numerous series of channels are provided for the transmission of the same amount of blood, but the chief element in its production has been demonstrated to be a quality inherent in the capillary vessels of dilating when irritated. The first and immediate effect of the irritation of any part is increased activity of the capillary circulation of the affected part. The capillaries dilate and the blood-pressure in them increases. This state is called *active hyperæmia,* or *afflux*, and occurs only as the result of irritation, and in wounds is the direct consequence of the local irritation produced by the traumatism that has at the same time produced the solution of continuity. In addition to this quality of dilatation displayed by the vessels themselves, it is probable that in most injuries there is present the added influence of the vaso-dilator nerves, affected indirectly through the sensory nerves of the implicated region, for it has been observed that excitation of a sensory nerve produces increased activity of the capillary circulation in the part in which the nerve originates. This active hyperæmia quickly subsides, without having produced any marked alteration in normal tissues, when the irritation ceases, if it has been temporary. But when the irritating

force has at the same time produced a breach of tissue, the hyperæmia is prolonged and quickly provokes active tissue-changes. These changes consist of *exudation* and *cell-germination*. Through the conditions which these new processes introduce into the wound, agglutination and ultimate firm union of the divided tissues by a more or less highly organized bond is effected.

Union of Wounds.—The preceding description of the capillary conditions that produce and characterize the active hyperæmia that follows wounds has been based upon the observations of Stricker.[1] The succeeding statements as to the character of the histological changes that attend the process of repair are derived from the same authority. The immediate effects of a wound have been traced to the point where an exudation of liquid from the hyperæmic capillaries has taken place. This exudation consists of an increased effusion from the vessels of nutritive plasma, or coagulable lymph, with some of the white corpuscles of the blood. The exuded plasma is appropriated by the cellular elements of the tissues. Under its stimulus these normal tissue-cells, which had become contracted and fixed, enlarge, absorb the basis substance in which they are embedded, multiply by segmentation, and again become amœboid and capable of development and organization into new tissue, being identical in character with embryonic tissue, the characteristic of which is that it is composed of amœboid cells, separated by narrow traces of intermediate or basis substance, and that these cells or masses tend to multiply actively by segmentation, and by a power of differentiation inherent in themselves produce the development and growth of the different organs and tissues of the body. The older the tissue becomes the greater proportion does the intermediate substance acquire, and the more slender are the cells and their processes. It is proper to say, therefore, that the divided tissues which are in process of reunion return, as a preliminary step, to the embryonic state. By the proliferation of the tissue-cells thus revivified new cells are developed, and the process of cell-formation continues until the breach is filled. The new material thus formed, consisting of cells embedded in a slight amount of gelatinous uniting substance, blends with the softened reverted tissue on either side and forms

[1] Disturbances of Nutrition and Pathology of Inflammation. The International Encyclopædia of Surgery, vol. i. New York: William Wood & Co., 1882.

a bond of union that within twenty-four hours is sufficiently formed to agglutinate the divided surfaces. The condition presented by the wound and adjacent tissue is well shown in the accompanying diagram of Shakespeare, Figure 1. There follow next, in due order, the vascularization and the connective-tissue transformation of this new tissue. Within a few hours new capillary loops extend into the cell-mass from the surfaces of the recently divided tissue. These inosculate freely with each other. With the restoration of the circulation through the new tissue the active hyperæmia in the adjacent blood-vessels subsides, and a retrograde metamorphosis of the cell-mass begins. Some of the cells become entirely converted into basis, or connective substance, while others remain, but contracted and changed in form by a similar transformation of portions of their mass at their circumference into basis substance. The basis substance speedily becomes quite stiff and fibrinous, and assumes a fixed character which is influenced by the adjacent tissue (Figure 2). The fixed character finally assumed by this basis substance determines the ultimate character of the new tissue. As a rule the highest development which the new material formed can reach is that of connective tissue, but a perfect regeneration, as regards form and function in the case of nerve, muscle, and bone tissue may be attained. The capillary network formed in the new tissue is at first more abundant than that of the adjacent tissue, so that the cicatrix appears as a fine red stripe (Figure 3); but in the further history of the tissue a tendency to condensation and atrophy is manifested, by which a large proportion of the newly formed vessels become converted into solid,

FIG. 2.—The same at a later stage. The clots in the capillaries almost removed, new vessels forming towards the gap, new connective tissue spindle-cells replacing the round cells. The epithelium has united on the surface.—*Shakespeare.*

FIG. 3.—The same later. The gap filled with new connective tissue and young blood-vessels.—*Shakespeare.*

fine connective-tissue strings, and the whole cicatricial tissue contracts and pales, becoming more dense and of a lighter color than the adjacent tissue (Figure 4). The repair of all breaches of tissue is accomplished by essentially the same process, subject only to minor differences arising from peculiarities of structure. This process consists—as has been now described—in a modification simply of the normal nutritive process at the seat of injury, by which the tissues to be repaired return to their embryonic state, and new embryonic tissue is formed between them with which they blend. By the organization and development of the new tissue a permanent bond of union is formed. In no case is union of divided tissue effected without the interposition of new material. When divided tissues are at once brought into perfect apposition, and there retained and shielded from disturbance, the amount of new tissue

FIG. 4.—Ultimate condition of the cicatrix formed in the wound, the young blood-vessels having disappeared.—*Shakespeare.*

required for the accomplishment of union will be extremely small, and may be with difficulty recognizable, but its existence in sufficient degree is nevertheless undeniable.

When rapid and uncomplicated union of divided surfaces takes place, union by *first intention,* or by *primary adhesion,* is said to have been accomplished. It is seen in its ideal perfection in the repair of many simple incised wounds, in which, even by the third day, the union may become so firm that extraneous means of retention are no longer necessary.

To secure this primary adhesion it is necessary that a close apposition of the divided surfaces be effected and preserved, that all sources of irritation be avoided, and that the conditions which favor nutrition in general be maintained. When any of these conditions fail to be secured, modifications in the typical process take place. The conditions that modify the processes of repair, and tend to prevent union by first intention, may be classified as: 1, *defects of apposition;* 2, *defects of protection;* 3, *defects of nutrition.* An analysis of the various conditions included in each of these classes is subjoined. Each is of importance in guiding the treatment to be adopted in any given case, and will repeatedly reappear for consideration in the succeeding pages of this work.

Defects of Apposition.—Close apposition of divided surfaces may be prevented by:

a. The natural gaping of the divided tissues in the absence of adequate means of coaptation and retention.

b. The character of the injury itself, as in superficial excoriations and burns, and in wounds in which there has been an extensive loss of substance, or by which a large, flat surface has been exposed.

c. The accumulation between the divided surfaces of blood and of wound-secretions.

d. The presence of foreign matter between the wound surfaces.

Defects of Protection.—By failure to properly protect a wound the injured tissues may be exposed to continued or repeated irritations. The sources of such irritation may be found in:

a. Motion, by which the apposition of the divided surfaces is disturbed, rupture of the new adhesive material produced, and

the conditions of the original injury renewed in tissues already weakened by that injury.

b. Direct mechanical violence, which includes not only rude handling, friction, and gross mechanical injuries of every kind, but also the less tangible injuries inflicted by minute foreign particles that may have been permitted to remain in a wound.

c. Substances produced by the multiplication within the wound of living micro-organisms introduced into it from without.

DEFECTS OF NUTRITION.—The causes of defective nutrition may be *general* and *local*. The general, or constitutional, conditions which produce defective nutrition have already been considered (see page 13). The local conditions are those which affect the circulation and the innervation of the part to be repaired. The primary active hyperæmia may be rendered excessive and prolonged, and nutrition be thus disturbed, by an improper position of the injured part or by any impediment to the return circulation. The prolonged application of cold impairs nutrition. Tension in the wound acts by obstructing the flow of the blood in the capillaries, and thus disturbing cell development and formation, a defect in nutrition.

The modifications which these various conditions, separately or in combination, may determine, may be divided according as the disturbances which they provoke result simply in prolongation of the healing and waste of the reparative material, or in arrest of nutrition and necrosis of tissue. The former may still be considered as examples of normal healing; the latter introduce disease into the process of healing, the most common manifestation of which is the condition of *inflammation*.[1] A brief consideration must be given to the phenomena which these modifying circumstances introduce into the processes of repair.

MODIFIED NORMAL REPAIR.—In injuries in which apposition is im-

[1] It is to be regretted that the term inflammation has been separated by recent pathologists from its traditional use to denote destructive disturbances of repair in wounds or tissues, and has been extended to cover, likewise, all the processes which attend the repair of wounds. By the present writer it will be used only in the restricted clinical signification which was given to it by the older writers, and with which it is still used by practical surgeons.

perfect, but in which all sources of further irritation may be avoided and the conditions that favor nutrition can be secured, an apparent modification of the healing process results from the greater amount and extent of the new tissue required to effect repair, but the process is essentially the same. Afflux, exudation, and cell-germination are continued until the gap is filled up; capillary loops are continuously extended into the new material as it is formed, and a progressive transformation of it into connective tissue, beginning in the portions first formed, takes place. Numerous granular eminences appear on the superficial layer of the new material, from the clustering of the new tissue about the capillary tufts. These are *granulations,* in technical nomenclature, and the new tissue is designated as *granulation tissue.* The process of healing thus accomplished is termed *healing by granulation,* or by ***second intention.*** In open wounds, when the granulations have reached the level of the cutis, or even sooner, they cease to grow; from the adjacent margins of epidermis a proliferation of epidermal cells takes place, which forms a film that gradually spreads over the granulating surface, forming an epidermal covering which completes the process of healing.

If surfaces that are granulating healthily can be brought and retained in contact with each other, prompt and permanent adhesion between them will take place. Union thus obtained is union by ***secondary adhesion,*** or ***third intention.***

The conditions necessary for securing the undisturbed production and organization of granulation-tissue are most frequently secured in subcutaneous injuries, in which cases the integument serves as a protection from further irritation, and especially from that produced by the entrance of infective material from the surface of the adjacent skin, or from dressings or other foreign material brought in contact with the injured tissues.

They may also be sometimes secured in open wounds which expose a flat surface by the rapid drying of the substances effused—blood and lymph—on the surface, so as quickly to produce a hard crust that forms a nearly impermeable layer, protecting and sealing up the granulating surface beneath from further irritation until its cicatrization is completed. This constitutes *healing by scabbing.* Though frequent in the repair of open wounds in animals, the greater sensitiveness to irritation possessed

by the tissues of man make this method of healing applicable in him to wounds of small extent only. The practical difficulty in securing the repair of open wounds is to protect them from irritation. Though other sources of irritation may with care be avoided, the infection of the wound surfaces by septic organisms from the adjacent skin or mucous membrane, or that are carried by the fluids or dressings that are applied to it, usually quickly takes place. The growth of these organisms, under the most favorable circumstances, produces a continuous irritation of the wound. Whatever the source of irritation, its immediate result is exaggeration of the pre-existing active hyperæmia, excessive exudation of plasma, and overproduction of embryonic cells. If the cells be in excess of the number that can be fixed and organized into the new tissue, they are floated away from the surface of the granulating tissue, suspended in the liquid plasma, forming a yellowish, bland liquid that bathes the free surface of the wound. This is *pus;* the process of its formation constitutes *suppuration,* and a wound in which it appears is a *suppurating wound.* The pus which bathes the surface of an open wound is, therefore, simply waste embryonic tissue cast off from a granulating surface which is not perfectly protected from irritation. Its production is not a necessary accompaniment of repair, but it is so rarely that an open wound can be protected perfectly from all irritation that, practically, suppuration is to be considered as a natural attendant upon the healing of open wounds in which union by first intention is not secured. The free escape of pus, as formed, is important to be secured, for, if retained, it may become itself a source of disturbance, by distention of the wound-cavity, and by the products of its decomposition. In wounds that are on the point of healing the pus becomes thin and scanty, and when the surface is exposed to desiccation the conclusion of the healing process not infrequently takes place under a scab.

Suppuration involves waste of the new material furnished for repair and entails delay in the completion of healing. As it occurs in the ordinary course of the healing of an open wound it does not involve the destruction of tissue.

Disposition of Effused Blood and of Dead Tissue.—The extravasations of blood, of varying amount, and the portions of dead tissue which an injured part presents as the direct effect of the injury may modify the

process of repair. In subcutaneous injuries blood-extravasations, to some degree, are almost always present, and in the great majority of open wounds there remains at least a slight layer of coagulated blood between the wound surfaces. The cavity of an open wound, in many cases, is filled with blood-clot, like a plug. Blood-clot may hinder repair, both by mechanically preventing apposition and by the irritation of the products of its decomposition and of the development of septic germs, to which it may afford a nidus for multiplication. In subcutaneous injuries blood-clots neither decompose nor become invaded by septic organisms. When the blood is infiltrated into the connective-tissue meshes it is quickly removed by absorption; when it remains as a mass filling up a gap between divided tissues it serves as a temporary mould for the support of the new embryonic tissue that is to form the permanent bond of union. The granulation cells produced at the borders of the divided tissues invade and appropriate its substance, capillary vessels follow the invading cells, and a process of clot-absorption and granulation-tissue development continues until the clot has disappeared and has become replaced by cicatricial tissue. In open wounds, when apposition of the divided surfaces can be secured and maintained, any slight film of blood-clot that may be present will not perceptibly interfere with the repair, but will be quickly appropriated by the germinating tissue-cells, and will disappear. In open wounds, in which union by first intention is impracticable, if the access of septic organisms can be prevented the behavior of the clot is the same as in subcutaneous wounds. The process of its invasion and replacement by granulation-tissue gradually extends toward its surface, till, after some days, what appears to be the clot will bleed when scratched. More frequently the superficial layer of the clot remains as a somewhat dried, dark-colored stratum, that is not invaded by the granulation-tissue, but acts as a protective shield to the deeper parts and is finally exfoliated, scab-like, when the cicatrization of the tissue underneath is nearly or quite complete. In open wounds which are not kept aseptic—and these constitute the vast majority of wounds—the blood-clot decomposes, liquefies, and is washed away in the discharges from the wound.

In all wounds there is devitalized tissue that must be taken care of. The removal of all dead tissue, when undisturbed by external agencies,

is accomplished by the same processes of cell-invasion and appropriation as have been described as the active agents in the disposal of blood-clots. The minute particles of dead tissue which exist along the track of an incised wound, or at the seat of a mild contusion, are quickly absorbed, and do not perceptibly interfere with the repair of the injury. Larger masses, likewise, if they can be kept from decomposition, and thus from becoming irritants, may be gradually removed by the same process and their place taken by new tissue. Inasmuch as the active agents in the production of decomposition are minute organisms from extraneous sources, the exclusion of these organisms from access to the dead tissue is of the first importance in promoting repair of all injuries. When the amount of dead tissue is very small, and the conditions for active repair are supplied, as in incised wounds in which apposition, proper nutrition, and freedom from irritation are secured, the constructive power of the living tissue is usually sufficient to resist the destructive tendency of organisms that may have gained access to the dead molecules, and no impediment to rapid repair is suffered. In subcutaneous injuries, the unbroken skin forming a perfect barrier against the infection of the injured parts by external organisms, the removal of dead tissue by absorption, without its becoming a source of irritation or complicating the repair of the injury in any other way than by mechanically preventing temporarily the apposition of living parts, is the rule. In open wounds, or in injuries that have become such by death of the skin, infection of the dead particles or masses and their conversion into irritants through decomposition takes place. The reparative efforts at the line of junction of the living and dead tissue are characterized by undue and prolonged hyperæmia, excessive exudation of plasma, and over-production of embryonic cells. The accumulating cells, instead of developing into granulation-tissue, degenerate into pus, and liquefaction of more or less of the zone of tissue that unites the dead and the living tissue occurs, producing a solution of the continuity between the living and the dead parts. The dead part thus cast off is called a *slough*. The rapidity with which a slough may be completely cast off will depend upon the activity of the natural nutritive processes of the particular tissue; the separation of bone or tendon, for example, being accomplished much more tardily than that of muscle or ordinary connective-tissue. When the surfaces of a wound have become thus

freed from dead tissue, its final repair will be accomplished by granulation with suppuration. Injuries which have been accompanied with much crushing and tearing are complicated not only by the presence of parts killed outright by the original violence, but also by portions of tissue whose vitality is greatly impaired, that are half-killed. Whatever adds to the irritation of the original injury, or interferes with the after-nutrition of these half-killed parts, endangers still more their vitality, and their absolute death may be determined by such subsequent conditions at any period of the reparative process. In subcutaneous injuries, and in open wounds that are kept free from septic infection, the gradual return of these half-killed tissues to their normal state takes place, and the repair of the injury is accomplished without the separation of any slough.

A review of the processes of normal repair which have been described shows that, when uninterrupted or unimpaired by external agencies or by unhealthy constitutional conditions, they are competent to remove dead tissue, to restore vitality to partly killed tissue, to furnish new material to repair breaches of continuity, and to accomplish the complete reorganization of this new material into living tissue. In the less favorable conditions which those open wounds present in which the access of infective organisms and the sloughing of dead tissue is unavoidable, as long as the free escape of the decomposing particles and of the pus is possible, and further injury by external agencies or by unhealthy constitutional conditions is avoided, uninterrupted repair still takes place, but with the waste of much reparative material, which escapes as pus from the exposed surfaces.

Though the processes by which repair is effected are identical in all these conditions, the practical results are very different according as repair is effected without or with suppuration. When repair without suppuration is accomplished, a minimum amount of new tissue is required, a minimum disturbance of the nutrition and the function of the injured part is suffered, and the most speedy return of the organ to its functional activity is secured. When suppuration attends repair the process of healing is prolonged, a greater drain upon the bodily powers is produced, prolonged disturbance of the nutrition and function of parts is suffered, and throughout danger of disaster from accidental complications is im-

minent. When repair is finally accomplished the new tissue is less highly organized than that which it has replaced, and permanent impairment of the function of the part is frequent.

Destructive Disturbances of Repair.—The turning point where the processes of normal repair become converted into processes of necrosis is the occurrence of prolonged stasis in the capillaries of the wound margins. By repeated or prolonged irritation of the already injured tissue—the lower the vitality of the tissue the less the irritation needed—the area of the primary active hyperæmia is increased, while a gradual slowing of the blood-current takes place in the vessels which are nearest to the point of irritation, until finally it ceases altogether, although at the periphery of the disturbed region the conditions of vascular dilatation and of accelerated blood-flow continue. Simultaneously with the retardation the white corpuscular elements of the blood—leucocytes—begin to crowd in numbers against the walls of the capillaries, and to penetrate them by their amœboid properties, and to accumulate in the perivascular tissue. An increased transudation of liquor sanguinis also takes place, and when stasis finally occurs the vessels remain choked with a crowded mass of red-blood disks. These conditions declare themselves by increased redness, heat, swelling, pain, and impairment of function in the affected part, and by more or less fever. A part presenting these symptoms is said to be inflamed, and the condition, as a whole, constitutes *inflammation*.[1]

When stasis has occurred the death of the tissue involved is imminent, but if further injury is averted and the general conditions favorable to repair are furnished, the stasis may shortly be overcome and the natural course of the circulation be resumed; *resolution* of the inflammation has been effected. If, however, irritation be renewed or continued, the stasis is prolonged and local death, or *necrosis* of tissue, takes place.

Inflammation of a wound involves, therefore, not only arrest of normal repair, but additional destruction of tissue; granulation is replaced by ulceration, and a new element of disturbance is introduced by the dead tissue which is to be eliminated. In the treatment of a wound it is important that inflammation be prevented, or that, if it be present to any

[1] See note on p. 29.

degree, its resolution be gained, and its destructive effects be limited. Inflammation is always due to some "defect of protection" (see page 28). When a wound is inflicted upon a tissue the injury is done at once; the extent and duration of the nutritive disturbances that follow are limited by the extent and character of the immediate injury, and they do not reproduce themselves in adjoining healthy tissues, except as the result of new injuries. The agents of injury may be gross or minute, may produce their effects through mechanical violence or by chemical action, may be microscopic germs or subtle poisons, but they all have the common effect of impairing the vital quality of—*i. e.*, injuring—the tissues they come in contact with. The practical fact, however, is always to be borne in mind, that the effect of any particular injury will always be greatly modified by the pre-existing condition of the tissue acted upon, and of the inherent resisting quality which it may possess. While inflammation is present the healing of a wound is arrested, and if it supervene in a wound in which agglutination has already taken place, the new-formed bond melts down and the wound gapes, presenting red, swollen, and everted edges. The local diseases of wounds—erysipelas and gangrene—and the general blood states that are dependent upon wounds—pyæmia and septicæmia—have a common initial lesion in wound-inflammation.

To prevent or to limit inflammation, or to lessen the effects of the disturbances induced by it, appear, therefore, to be indications of the greatest importance to be met in the treatment that a wound shall receive. The conditions of inflammation, however, do not arise spontaneously, nor do they perpetuate themselves. The continuance or the extension of an inflammation results only from the continued or extending action of some irritant. The more gross irritants, as motion, friction, or other mechanical violence, or ordinary chemical agents, are readily detected, and, usually, as easily guarded against. In the remarks upon classification of wounds, the difference in the behavior of subcutaneous and open wounds, as regards their liability to inflame, was mentioned, and the inflammatory disturbances likely to result from the access of infective material of extraneous origin noted. It was still further noted that so great was the difference between the behavior of wounds in which there was much devitalized tissue left behind by the wounding agent, and those in which there was little, that it constituted a basis for important clinical classifi-

cation. That the mere presence of devitalized tissue alone is not the cause of these disturbances, however, is shown by the fact that similar injuries, if subcutaneous, escape them in great measure. The mere presence of ordinary air alone is not the cause of these disturbances, as is shown by the harmlessness of surgical emphysema, and the freedom from injury exhibited by animals through whose peritoneal cavity unfiltered ordinary air has been passed for hours. The only conclusion is that, in the cases in question, the cause of inflammation, and of the wound-diseases that are associated with it, is to be found in the mutual reaction of devitalized tissue and some agent brought by the air, or otherwise introduced from without. Wound secretions, when accumulated in excess of that which can at once be converted into living tissue, and blood-clots, are but forms of devitalized tissue, and display the same reaction with infective agents. The importance, therefore, of securing the most complete removal of blood-coagula and of wound-secretions from wounds that cannot be absolutely protected from infection, depends more upon the inflammation-producing reaction which they will suffer with agents brought in contact with them from without than it does by the defects of apposition which they produce. Simple defects of apposition, as has been seen, entail only prolonged repair; the infection of devitalized tissue, of blood-clots, and of wound-secretions introduces continuous and active local irritation, and bathes the tissues with products, the absorption of which into the circulation poisons the very fountain of life.

The inflammation which complicates the repair of open wounds manifests varying degrees of intensity, and of tendency to extend in different cases. It may be limited to but a small extent of tissue adjacent to the wound-margins, and, with the separation and removal of the shreddy sloughs formed by the dead particles of tissue originally in the wound, and of the liquefied blood-clots, or by the escape of the accumulated secretions, may quickly subside and permit the resumption of the healing of the wound by granulation. It may diffuse itself upon the skin, forming a superficial erysipelas, or may extend more deeply along the planes of connective tissue that may have been opened up by the wound, constituting a diffuse cellulitis or a phlegmonous erysipelas. The amount of necrosis also may present every grade of extent from that of molecular disintegration upon the surface of the wound to the death of large masses

of tissue. The amount of constitutional disturbance produced by the absorption of matters generated in the inflamed tissue varies likewise from a slight ephemeral febrile reaction to fatal septicæmia and pyæmia. It is not in the scope of this work to discuss in detail the various phases of the destructive disturbances which may complicate wounds. Sufficient only can be presented to serve as a groundwork upon which to base a rational and comprehensive preventive treatment, for the treatment of a wound cannot be considered as accomplished until all the possible safeguards against the disturbance of its repair have been secured.

CHAPTER III.

THE RELATIONS OF MICRO-ORGANISMS TO WOUND-DISTURBANCES.

Results of Defects of Protection—Causes of Decomposition of Animal Tissues—Researches of Pasteur and Tyndall—Universal Prevalence of Micro-Organisms—Organisms Pathogenic to Man—Resisting Power of Living Tissues—Conditions Contributing to the Growth of Organisms—Pyogenic Organisms, Staphylococci, Streptococci—Conditions Contributing to Increase or Attenuation of Virulence—Bacillus Coli Communis—Bacillus Pyogenes Fœtidus—Bacillus Pyocyaneus—Relation of Micro-Organisms to Suppuration, to Septicæmia, to Pyæmia—Argument from the Results of Antiseptic Wound-Treatment—Experience at Glasgow, Halle, Munich, Bellevue Hospital—Results of Amputations, of Compound Fractures—Wide Diffusion of the Results Obtained—Extension of the Field of Operative Surgery—Résumé.

THE importance of the considerations which have been under review in the preceding chapter, as to the mechanism of healing and of the disturbances that may complicate it and convert its beneficent constructive processes into those of local embarrassment and death, and of possible general danger, have their greatest demonstration in the aid which they have given in directing a search for the ultimate causes of the changes that result in disorders of repair. Only with accurate knowledge of these causes can intelligent effort to prevent their access, to destroy them, or to make them harmless be made. Without such knowledge wound-treatment is an empirical groping ; with it, it becomes an exact science. It has been seen that defects of reparative power, constitutional and local, may hinder repair ; that defects of apposition prolong repair and occasion waste of reparative material, but that in defects of protection are found the conditions that produce arrest of repair and destruction of tissue ; that the defects of protection which occasion the most frequent and most serious wound-disturbances are those which permit the access of extraneous organisms to wounds ; that those wounds manifest these

disturbances in the highest degree which present the largest amount of devitalized material ; and, finally, that, with the exception of the transient inflammations due to repeated traumatism, the various inflammatory and septic accidents that wounds suffer are due to infection of wound surfaces and secretions by minute living organisms from without.

The causes of the decomposition of animal tissues, and the laws, methods, and products of their activity, must therefore be regarded by the surgeon as matters of fundamental importance in all considerations as to the treatment which he shall give to wounds. As to the causes of decomposition in animal tissues, they are of the same general character as those which determine decomposition or fermenting changes in organic matter of any kind. The researches of Pasteur, of Tyndall, and their co-laborers, have clearly and definitely settled the scientific truth that no decomposition or fermenting change will take place in organic matter, except after the introduction into it from without of living organisms that find in its substance pabulum meet for their nutrition, and, as the result of their multiplication within it, induce its decomposition. Even the most putrescible substances, as urine, and animal and vegetable infusions, remain unchanged for an indefinite period when they are received in sterilized receptacles and are kept in an atmosphere which is purified from organic particles.

Such germinal particles "abound in every pool, stream, and river. All parts of the moist earth are crowded with them. Every wetted surface which has been dried by the sun or air contains upon it the particles which the unevaporated liquid held in suspension. From such surfaces they are detached and wafted away, their universal prevalence in the atmosphere being thus accounted for. They are endowed with a power of flotation commensurate with their extreme smallness and the specific lightness of the matter of which they are composed." (Tyndall).

They are transferred from surface to surface by contact as well as by air-flotation. Many of the organisms which are pathogenic to man have their constant abode in the recesses and surfaces of the skin and the mucosa of the alimentary canal of human beings, and they are being constantly shed in innumerable hosts attached to the epithelial scales that are being cast off, or diffused in the albuminous liquids that are ejected. All materials used by man, or remaining any length of time

in the vicinity of men, are therefore presumably contaminated by such organisms. The more dense and numerous the aggregation of men, the more certain and abundant the dissemination of these parasitic organisms.

Since these agents of infection are particles and not gases, they are not uniformly diffused, but are likely to be more numerous wherever and whenever the conditions that favor their growth and dissemination are active.[1] This implies the contrary truth also, that at times, and in certain conditions that promote purity of the atmosphere, indefinite volumes of it may be free from septic germs altogether. Particular germs of the same species differ also as regards their readiness for development ; some are fresh, others old ; some are dry, others moist. The conditions which modify the germination of gross seeds affect in an equal manner these minute germs. The external conditions of warmth and moisture hasten their development ; cold and absence of moisture retard it. The species of micro-organisms that have been identified as capable of producing disease in the human body are comparatively few in number. Of the greatest importance, however, from its power in limiting their disease-producing effects, is the power with which the living tissues of the body are endowed of resisting to a certain extent the action of these organisms, and of destroying them. As a consequence of this these organisms are never found in the fluids or tissues of the healthy living body, notwithstanding they abound in the air by which it is encompassed, they rest and develop in the secretions that issue on the surfaces and gather in the depressions of the external covering of the

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[1]M. Miquel's experiments at the observatory at Montsouris in Paris show that they are most numerous in the lower strata of the air. While in a cubic metre of air at the top of the Pantheon he found but twenty-eight of them, the same quantity of air in the park of Montsouris contained forty-five, and in the mairie of the fourth arrondissement, four hundred and sixty-two. Great agglomerations of men furnish the most of them. The air in the interior of Paris is nine or ten times richer in them than that in the neighborhood of the fortifications. The dusts proceeding from substances in a state of putrefaction, unhealthy pus, and the dejections of the sick, are charged with them. After two or three days of moist and rainy weather, the atmosphere is in a condition of extreme purity.

body, and they swarm in the secretions and contents of the alimentary canal. To this resisting power in living matter is due the fact that those organisms which may have gained access to the tissues exposed by a wound do not develop and multiply and produce decomposition in such a wound when speedy and complete contact of its surfaces is secured and maintained. On the contrary, whatever organisms may be present in such a wound are attacked by the living cells that are active for its repair, and are engulfed and disintegrated by them.[1] Should, however, the coaptation of the wound surfaces be imperfect, so that recesses or cavities remain in which fluid exudates accumulate, this germicidal function of the tissue cells is prevented since they are no longer kept in contact with the bacteria floating in the fluid, in which also are afforded the best of conditions for the development of whatever bacteria might have gained access to them.

Bacteriological research, especially the labors of Ogston, Passet and Rosenbach, has demonstrated that certain spherical organisms—*micrococci*—and less frequently certain rod-shaped organisms—*bacilli*—are the ones that are concerned most frequently in the production of the inflammations and infectious diseases that complicate wounds. The characteristic appearance of these forms is well shown in the accompanying cut (Fig. 5), in which are shown the various forms present in the discharges from a case of compound dislocation of the thumb, in which no attempt to prevent their development had been made (see Cheyne, "Antiseptic Surgery," p. 235, Case 1).

The conditions in which these different forms of organisms flourish differ, and the results, in general, determined by them also differ. In every wound which smells suspiciously the rod-shaped organisms are present in large numbers. Where a bagging wound or a deep sinus is present, the discharge is apt to be fetid and contains many rod-shaped

[1] "Natural immunity is due to a germicidal substance present in the blood-serum, which has its origin (chiefly at least) in the leucocytes, and is soluble only in an alkaline medium. Local infection is usually resisted by an afflux of leucocytes to the point of invasion; but phagocytosis is a factor of secondary importance in resisting parasitic invasion. * * * Natural immunity may be overcome by infection with an excessive number of pathogenic bacteria and their products, as contained in a culture, or by an unusually virulent variety."—Sternberg, Immunity and Serum Therapy, 1895, p. 31.

organisms; but when an incision converts the pouch into a superficial wound, the spherical organisms again become predominant (Ogston[1]); and in the discharges which flow from flat surfaces in general, where stagnation is avoided, the spheres exist in preponderating numbers. The

FIG. 5.—The Micro-organisms of Septic Wound Discharges (*Cheyne*).

vital energy of these organisms of putridity is weak; they are quickly killed by weak antiseptic agents; they do not survive, much less grow in the blood; they do not invade living tissue, but attack only dead tissue, and when they affect the general system it is by the absorption into the blood of the putrid liquids and gases that are generated at the original site of putrefaction. The septicæmia that is produced depends for its continuance upon the continued activity of the local putrefactive process, and disappears when this external supply is stopped. Wounds containing much putrefiable material, when they are at the same time of such a character as to hinder the ready escape of the wound-secretions, afford the most perfect conditions for the luxuriant development of these organisms. The removal of sloughs, the opening of sinuses, and the establishment of free outlets for the secretions, tend to banish the organisms by removing the pabulum necessary for their existence.

The spherical organisms—micrococci—manifest characteristics quite different from those displayed by the rod-shaped, and exhibit a relation to wound-disturbances much more extended and difficult to control. Micrococci are minute round cells, generally under one micro-millimetre

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[1]Report upon Micro-Organisms in Surgical Diseases. By Alexander Ogston, M.D. British Medical Journal, March 12, 1881.

in diameter, growing in pairs, short chains (*streptococci*), or groups of smaller or larger size (*staphylococci*), this cycle being repeated on the addition of fresh pabulum. In a given specimen of pus they will not be uniformly distributed, and they will vary in size, while in different specimens their numbers may vary greatly. One specimen of pus examined by Ogston contained forty-five millions per cubic millimetre, while two others contained in the same bulk only nine hundred. The decompositions that they induce are not those of common putridity. If they are introduced into a fluid and there cultivated they produce no offensive stench. In most acute abscesses where they abound no bad odor is detectable, and in general their presence or absence is not indicated by any smell.

FIG. 6.—Staphylococcus pyogenes aureus (*Rosenbach*).

FIG. 7.—Streptococcus pyogenes (*Rosenbach*).

The most common pus-producing micro-organism is the *Staphylococcus aureus,* an organism the normal habitat of which may be said to be the external surface of the human body and of moist mucous membranes, whose conditions seem especially favorable for its existence. It derives its name from the characteristic golden yellow color which masses of it present when gelatin cultures of it are made. Its virulence is moderate and from infection by it an acute suppurative inflammation is excited which remains circumscribed. Identical in form with this golden organism is another staphylococcus which is distinguished from it by the absence of pigment and by being less pathogenic. This parasite, the *Staphylococcus albus,* is the most common organism on the surface of the body; it nests itself especially in the deepest parts of the follicles of the skin beyond the reach of the usual means of cutaneous disinfection. It is feebly pathogenic, so that it usually does not interfere with the healing of wounds, but under favoring conditions is capable of exciting suppura-

tion. Most so-called stitch-abscesses are caused by it. The presence of dead spaces filled with blood-clot and serum, necrotic bits of tissue upon the wound surfaces, impairment of the nutrition of the wound edges by too tight sutures or too much tension to the wound flaps, are the most common conditions that rouse this organism into activity. The association of both forms in suppurating foci or surfaces is frequent. The manner of their relation to the tissue elements is shown in figure 8.

A staphylococcus identical in other respects with the two just mentioned, and differing only by the formation of a lemon-yellow pigment, instead of a golden yellow, has been detected in occasional instances associated with the others ; also another infrequent form has been identified, of undetermined pathogenic qualities, the *Micrococcus pyogenes tenuis.*

FIG. 8.—Vertical section through a subcutaneous abscess caused by inoculation with staphylococci, forty-eight hours after infection. x 950. (*Baumgarten.*)

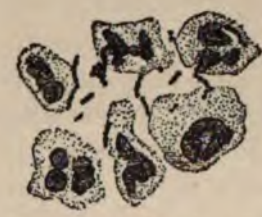

FIG. 9.—Pus containing Streptococci. x 800. (*Flugge.*)

The *Streptococcus pyogenes* is a widely distributed micro-organism, and has frequently been found upon the nasal, buccal and vaginal mucous surfaces of healthy individuals. It is a more virulent organism than those in the staphylococcus group; in addition to its local irritating and pus-producing effects it tends to invade the lymphatics and diffuse itself along their spaces and trunks (see Fig. 10), producing the phenomena of erysipelas. It is frequently associated with other pathogenic organisms, and by the mutual reaction of the products of these

an increased virulence of infection may be created. The following remarks upon this phase of bacterial-infection by Sternberg (Manual of Bacteriology, p. 280) are both pertinent and important: "The fact that pathogenic bacteria may attain an intensified degree of virulence by cultivation in the bodies of susceptible animals was demonstrated by Davaine many years ago, and is fully established by the experiments of Pasteur and others. The reverse of this—attenuation of virulence as a result of cultivation in artificial media—is also well established for several pathogenic species. Now it appears that the attenuated streptococcus is far less likely to give rise to erysipelas or to puerperal infection than is the same micro-organism as obtained from a case of one or the other of these infectious diseases. The same is probably true also of staphylococcus aureus and other facultative parasites which are found as saprophytes upon the surface of the body and upon exposed mucous membranes in healthy persons. And it is not improbable that attenuated varieties of these micrococci which find their way into open wounds, or into the uterine cavity shortly after parturition, if they escape destruction by the sanguineous discharge, acquire increased pathogenic power from their multiplication in it, as a result of which they are able to invade the living tissues. But it appears probable that infection through open wounds does not depend alone upon the potency of the pathogenic micrococci present in them, but also upon the absorption of chemical poisons produced by septic (putrefactive) bacteria which weaken the vital resisting power of the tissues. Gottstein, as a result of experiments made by him, is of the opinion that the resorption of broken-down red blood corpuscles favors infection by pathogenic bacteria present in wounds; and he has shown that the injection into animals of certain toxic substances which destroy the red corpuscles in the circulation makes them susceptible to the pathogenic action of certain bacteria which are harmless for them under ordinary circumstances."

FIG. 10.—Streptococci in lymph-spaces. Section from a margin of an erysipelatous inflammation. From a photograph by Koch. x 900.

Koch explains the gangrene-producing effects of the organisms investigated by him, as follows : " Introduced by inoculation into living

animal tissues, they multiply, and as a part of their vegetative process they excrete soluble substances which get into the surrounding tissues by diffusion. When greatly concentrated, as in the neighborhood of the micrococci, this product of the organisms has such a deleterious action on the cells that these perish, and finally completely disappear. At a greater distance from the micrococci the poison becomes more diluted and acts less intensely, only producing inflammation and accumulation of lymph corpuscles."

Ogston, likewise, concludes that it must be by the noxious substances generated during their growth that they irritate the tissues, and cause inflammation and suppuration. "It may be looked upon," he says, "as being far from unlikely that the very reason why micrococci produce suppuration is that they, in growing among the tissues, generate some acrid ptomaïnes that may correspond pretty closely in their effects with those of injections of turpentine or other caustic liquid."

The streptococcus infection is characterized by violence of local inflammatory reaction, by a tendency to spread and by marked constitutional disturbance.

The *Bacillus Coli Communis* (Figure 11) is a constant and abundant organism that has its special habitat in the intestinal canal. It is usually present in normal dejecta and abounds in diarrhœal discharges. It is also found outside the body both in air and in water and in putrefying fluids. It is a pyogenic organism and plays a large rôle in determining the suppurations that follow wounds or lesions of the intestinal canal, and especially those in which the peritoneal cavity is invaded.

FIG. 11.—The bacillus coli communis. x 1,000. (*Escherich.*)

The *bacillus pyogenes fœtidus* and the *bacillus pyocyaneus* are occasional factors in suppurative processes. The former has been found in the pus of perirectal abscesses and is a source of the offensive odor that characterizes such collections of pus. The latter is found occasionally in the pus of open wounds and gives to it a greenish or blue color. It is by itself feebly pyogenic and is sometimes found in wound secretions that are serous.

The relation of micro-organisms to suppurative inflammations is one of great interest and importance in its bearing upon the healing of

wounds. While not all forms of micro-organisms are capable of exciting suppuration, nor are micro-organisms the only agents that are competent to excite suppuration, yet the proof is conclusive that the suppurations and suppurative diseases that complicate wounds, and the acute suppurative inflammations that occur in man, are caused by the vital activity of various forms of micro-organisms.

By the observations of Ogston, published in 1881, of Rosenbach in 1884 and of Passet in 1885, these facts were established and the varieties and natural history of the organisms commonly at fault were identified and described. During the years that have since elapsed, by the work of a large number of other and independent investigators the conclusions of these pioneer observers have been corroborated and amplified until their truth is now no longer the subject of dispute but has become universally accepted and is now the chief cornerstone of the edifice of modern surgery. When wounds suppurate the intensity of the suppuration is proportionate to the character, the numbers and the activity of micro-organisms by which it has become infected, which not only multiply in the wound secretions, but also infiltrate the adjacent tissue until by the formation of a dense layer of granulation tissue—that is a wall of actively resisting cells—further invasion is limited.

It is hardly necessary to observe that the foregoing statements apply equally to the causes of the suppuration which usually accompanies the healing of wounds by granulation, for the production of pus upon a wound surface is the result of irritation of that surface, and depends for its continuance upon a condition of the tissues alike in kind, and differing only in degree and extent from that which constitutes inflammation, in the surgical sense of the word. The products of the ordinary micrococcus, as it multiplies in the secretions of a wound on whose surface it has been deposited, are but little irritating, as has been shown by its feebly noxious effects when injected into the tissues of living animals; but it is sufficient to provoke the prolonged hyperæmia, the overflow of plasma, and the excessive production of cells that constitute suppuration.

Thus far in the consideration of the relations of micro-organisms to wound-disturbances, attention has been directed chiefly to their local effects. It has been seen that suppuration, phlegmonous inflammation, gangrene, and erysipelas are the direct result of the vital activity of

certain forms of micro-organisms ; incidentally reference has been made to the effects produced upon the whole system by the absorption into the blood of the noxious products or ptomaïnes that result from the changes in the pabulum upon which they feed, to which the general term *Septicæmia* is applicable. This demands farther consideration, and also the closely allied state in which, with a septic condition of the blood, there is associated multiple abscesses in various organs of the body, *Pyæmia.*

Blood-poisoning and metastatic abscesses claim recognition as the most redoubtable processes that can complicate the healing of wounds. Their close association with faults of repair in wounds, and the development of unhealthy conditions in the wound-secretions have always been too distinct to fail of recognition, so that the clinical fact that these processes were consequent upon the absorption of noxious or septic matters produced in the wounds was long appreciated before experimental investigation attempted to determine and isolate the essential cause of their hurtful character.

The results of the innumerable observations made by many investigators since the publication of Ogston's memoir in 1881 have but served to confirm the conclusion arrived at by him, that there is no such disease as septicæmia or pyæmia *per se,* such conditions being merely secondary in the order of the morbid process, and dependent on the existence of local foci of micrococcus growth. For the focus of the disease never exists in the blood, but always in the tissues, whence the ptomaïnes generated in micrococcal proliferation pass into the circulation to act as poisons or intoxicants, though separate individuals or small groups of the micro-organisms may be conveyed by the blood into other situations, so as to reproduce among other tissues the disease of the parent focus. In his summary he uses the following language : " Phlegmonous inflammation, septicæmia, pyæmia, and septico-pyæmia are all micrococcus poisoning, varied, however, according as ptomaïne intoxication or the local tissue reaction becomes more prominent. Every feverishness, from an inflamed throat or finger, is a septicæmia in a mild degree, and may pass into a severe form. Ptomaïnes pass into the blood, and coincidently a few individuals of the micrococcus may be found to have wandered from the local disease and to be circulating in the blood, dead or half dead, owing to the unsuitability of the medium where they are, and the unfa-

vorable influences of the forces of the tissues. If removed from the blood they rarely grow when put into suitable medium. They are all eventually extruded or consumed. But if the individual be subjected to depressing influences, the ptomaïne poisoning may not be the only phenomenon observed. As the symptoms become more severe, and the micrococci more numerous in the blood, the weakness of the individual becomes greater, and the resisting power of his tissues less, so that the micrococci are able to live in the blood, where previously they found this impossible. They multiply and form small groups that increase in size until they are too large to pass through the capillary net-work, and therefore are caught and detained in lungs, liver, or some other part. There they continue to increase during life, perhaps even for a time after death, and furnish their contribution of poison to the system. Or it may be that, though unable to multiply in the blood, they here and there throughout the body find spots suitable for their development, where they can multiply and form the foci of suppuration that mark the form for which we usually reserve the name *pyæmia*. The pyæmia secondary foci are usually in lung, or liver, or joint, but may equally well occur in lymphatic glands, secreting glands, or even in connective tissue."

According to Warren (Surgical Pathology and Therapeutics, 1895), the organism which is almost always found in the blood of septic cases is the streptococcus pyogenes. Much difficulty is experienced in finding micro-organisms in the blood of human beings affected with septicæmia owing to the fact that they are rapidly swept through the large vessels, and are therefore found in the general circulation during but brief periods of time. They accumulate, however, in the capillaries, and there have an opportunity to multiply.

In pyæmia, however, there is usually present an embolic element derived from the disintegration of infected thrombi from the venules of the primarily infected region. Such fragments, laden with organisms, are swept into the general circulation and become the source of multiple new foci of suppurative inflammation in distant parts of the body.

In concluding the present inquiry into the relations of micro-organisms to wound-disturbances, attention should be directed to the results which have been obtained by methods of treatment that tend to prevent the access of such organisms to wounds, or to lessen their activity,

if already present. By themselves alone considered these statistical clinical data would afford only presumptive evidence at best ; but when taken in connection with the results of careful, minute, guarded, experimental investigations which have occupied attention in the preceding portion of this chapter, they appear as the strongest kind of corroborative evidence of the correctness of these results. Every wound treated in accordance with the theoretical indications experimentally demonstrated becomes a check upon the correctness of the conclusions deduced from the results obtained by the experiment.

During the years which have elapsed since Joseph Lister, influenced by the results of Pasteur's investigations into the causes of putrefaction, began the use of carbolic acid as a germicide in the treatment of compound fractures in the Glasgow Infirmary, the theory that noxious germs, conveyed into wounds from without, were the essential causes of wound-disturbances, has been clinically tested upon a vast scale by many methods and by a multitude of independent observers.

In the Glasgow Infirmary, at the time Mr. Lister began his methods of treatment, based upon the principle of antagonizing germ-activity, infective diseases were constantly present, and became at times so prevalent that the wards had to be closed. Out of thirty-five amputations, of all kinds, done by him in two years, sixteen died, of which deaths almost all were due to infective disease—thus of the six deaths following amputations of the upper extremity, four were due to pyæmia and one to hospital gangrene. After the adoption of his new methods, though they were as yet crude, during three years, there were but two deaths from pyæmia after amputation, out of forty amputations performed, and in one of these the pyæmia existed prior to the operation. These were the only cases of pyæmia which occurred in Mr. Lister's hospital practice during these three years, though there were twenty-two compound fractures and several compound dislocations during this time. One case of erysipelas, and one or two cases of hospital gangrene, of a mild type, complete the list of infective diseases that occurred during this time.

At the Halle Clinic, previous to 1874, the deaths from pyæmia and septicæmia had been so numerous that the entire closing of the hospital for a time seemed necessary. Upon the institution of the Listerian methods of treatment at the date mentioned these accidents at once

ceased, and three years later Volkmann reported that not a single case of pyæmia or septicæmia had occurred during that time among the patients thus treated by him.

In 1878 Professor Nussbaum tabulated the results of the treatment of wounds, at the Surgical Clinic of the University of Munich, before and after the adoption of antiseptic methods, thus :

Before.	*After.*
"Injuries of the head, compound fractures, amputations and excisions, in fact, almost all patients in whom bones were injured were attacked by pyæmia. For example, of seventeen cases of amputation, eleven died from this cause. Even patients with severe whitlow died of it.	No pyæmia.
"Hospital gangrene had got the upper hand to such an extent, that in spite of continuous water baths, in spite of the use of chlorine water, or the actual cautery, finally eighty per cent. of all wounds and ulcers were attacked, large arteries being opened into.	No hospital gangrene.
"Almost every wound was attacked with erysipelas.	No erysipelas."

In the Bellevue Hospital of New York, according to the statements of Dr. Stephen Smith (The Comparative Results of Operations in Bellevue Hospital—Medical Record, October 17, 1885), in the pre-antiseptic period, amputation wounds rarely, if ever, recovered except after long-continued suppuration. The larger amputations were terribly fatal. Suppuration, with its sequelæ, septicæmic, pyæmic and hectic fevers, was the scourge of the surgical wards.

Again, speaking of the course of wounds in general, he says: "If the wounds were large, on the second or third day the fever announcing suppuration began, and from this date, for weeks after, the dressings were changed daily, one, two or three times. The pus basin, the irrigator and the dressing forceps were in constant demand. In many wounds the suppuration was so profuse that vessels were placed under them which received the continuous discharge. The fever generally ran high, with consequent exhaustion and depression of the patient. Septicæmia, as

we now understand it, was the intermediary fever of that day and was regarded as a usual, if not a necessary, sequel of all considerable operations. Following this fever, or rather insidiously engrafted upon it, were chills, fever and profuse sweatings, now recognized as pyæmia, but then regarded as only another stage of surgical fever. Few survived this fever, and in the diffused or metastatic abscesses revealed at the autopsy the surgeon discovered a cause of death quite beyond his power to prevent, control or even comprehend. The vast change in the progress of operated cases during the past ten years (1875 to 1885) can scarcely be realized. Surgical fever, with all its disastrous variations, is in practice rare. Pus, as an outcome of surgical operations, is a thing of the past. The wound is now dressed with no expectation that fever will rise, or that suppuration will occur, or that the dressings will require renewal on account of the presence of pus. The patient sleeps and eats well from the first, and the surgeon removes the dressing only to find the wound united."

Schede, in the fasciculus on amputations and resections in Pitha and Billroth's "Handbuch," gives comparative tables of 321 uncomplicated amputations performed aseptically, and of 377 treated by older methods. The first were under the care of Busch, Schede, Socin, and Volkmann. The later were furnished by Bruns, Bardeleben, and Billroth. Of the aseptic cases 14 died, or 4.4 per cent. ; of the ordinary cases 110 died, or 29.18 per cent. The causes of death were tabulated as follows :

	Septic cases.	Aseptic cases.
Pyæmia	72	0
Septicæmia	19	1
Erysipelas	2	1
Trismus	0	1
Pyæmia simplex	6	1
Hæmorrhage	3	1
Exhaustion	2	1
Shock	6	8
	110	14

A similar immunity from septic sequelæ in amputation wounds, the cases aggregating a much larger number and under the directing care of one man, is reported in 1894 by Estes, of Pennsylvania, who dur-

ing the preceding twelve years in the hospital under his direction had 340 major amputations, of which all but 19 were done for injuries usually the result of great violence. Two of this number were already exhausted by septicæmia when received and subsequently died therefrom, but among the entire number remaining there was no case of pyæmia nor of septicæmia. The total number of fatalities was 27, or 7.9 per cent., the chief cause of mortality being acute anæmia and shock (Medical Record, November 3, 1894).

Even more remarkable and significant as a test of the value of the practicable application of anti-bacterial methods in the treatment of wounds are the results obtained in the treatment of compound fractures of the larger bones, injuries in which the amount of laceration and contusion of the soft parts, and the extravasation of blood into the connective tissue spaces is often such as to present conditions most favorable for septic infection, and under methods of treatment formerly in vogue led as a rule to prolonged suppuration, very frequently to profound septicæmia and pyæmia, to avert which amputation was often resorted to. Under methods of treatment based upon the principles of bacterial activity these suppurative and septic complications have become insignificant and the undisturbed union of such fractures has become the rule. Thus of 1,000 consecutive cases of compound fracture reported by Dennis (System of Surgery, I, 529), treated by antiseptic methods, while 82 died within 48 hours as the immediate result of traumatism, and 19 others died at later dates from various causes, there was but one death out of the entire number due to wound infection. Nor has this immunity from serious wound infection in the case of compound fractures been limited to the work of a few ; it has been the common result secured by surgeons everywhere. Thus, during the period of ten years from 1887 to 1897, inclusive, of 252 cases of compound fracture of the large bones under the author's personal observation, no case of septicæmia, much less of pyæmia, occurred, and during the same period in twenty-one cases of fracture of the patella, the knee joint was opened and the fragments sutured together without any inflammatory sequel.

The common experience of surgeons in all seasons and in all parts of the globe is that in the treatment of wounds just in proportion as it has been practicable to carry out methods by means of which the access of

micro-organisms to, or their development in wounds could be prevented or diminished, disturbances of repair have been escaped and healing has been sure, speedy and perfect. Extensive contused and lacerated wounds may be conducted to healing, blood-clots may remain, serving as pabulum and scaffolding for the development of new tissue, and dead tissue may separate and be absorbed or removed without in any case giving rise to destructive inflammation. The earlier claims of Mr. Lister and his pupils as to the undisturbed favorable progress of the healing of wounds which were submitted to the special antiseptic methods of that surgeon have been corroborated by the experience of an entire generation of surgeons with many different methods and agencies for accomplishing the same purpose, viz.: the prevention or the limitation of wound infection by extraneous organisms.

But in addition to this the effect of the knowledge upon the part of surgeons that the prevention of septic accidents in wounds was so largely under their own control has been to revolutionize the practice of surgery and to open to common operative effort classes of affections hitherto rarely submitted to operation, such as osteotomy for the relief of deformities, operations upon the cranium and spinal canal for intracranial and spinal affections, operations for the radical cure of hernia, operations upon the kidneys, upon the gall passages, upon the pelvic organs of women, for affections of the appendix vermiformis, and indeed all of intraperitoneal surgery.

Finally, for the purpose of bringing this chapter to a close, a brief résumé may be made of the facts which have been established as to the relation of micro-organisms to wound-disturbances. Three great groups of phenomena present themselves from which to draw pertinent observations, viz.: 1, the behavior of wounds which were exposed to the access of micro-organisms or their germs, and which presented conditions favorable for their vital activity ; 2, experimental research as to the nature and the effects produced by the different species of micro-organisms ; and, 3, the effects upon the course of healing in wounds produced by protecting them from germ invasion or by destroying or diminishing the activity of such as may have gained access to them.

In the first class are all open wounds, in which the conditions favorable for the development of activity of germs sown upon them become the

more pronounced in proportion as the amount of devitalized tissue, and of blood-clot, and the number and depth of recesses for the reception and retention of wound-secretions increase.

Observation of this class records that invariably their repair is disturbed by putrefaction and sloughing of the devitalized tissues, by decomposition and liquefaction of the blood-clots, by inflammation of the wound-margins, and by a prolonged process of suppuration and granulation, and, in a certain number of cases, by grave septicæmia, and by pyæmia.

In the second class stand out the facts that no decomposition or fermentation takes place in organic matter without the agency of some form of micro-organism; that when no extraneous organism has gained access to a wound, no wound-disturbance occurs; that certain forms of micro-organisms are always found associated with certain forms of wound-disturbances; and, finally, that these micro-organisms, when isolated and introduced anew in sufficient amount among tissues previously healthy, are capable of exciting here the same diseased action with which they were originally found associated.

In the third class are subcutaneous wounds, in which the unbroken skin forms a perfect shield against the invasion of noxious organisms from without ; wounds involving the integument, in which apposition of the divided surfaces can be secured and maintained, and the retention of wound-secretions prevented, and in which the inherent force of the constructive power of the healing tissues is great enough to destroy whatever germs may gain access while the surfaces are exposed ; and wounds of every class in the treatment of which adequate measures have been used to prevent the access of germs, or to destroy them, or prevent their development if present.

Clinical observation records, for all the members of this third class in which protection from invasion of micro-organisms is secured in various ways, a common immunity from wound-disturbances. The repair of subcutaneous wounds is, as a rule, free from suppuration, inflammation, and sloughing, or other serious complication, even though involving much contusion and laceration of soft parts and extensive effusion of blood. Union by first intention, without disturbance, accident, or delay, is the rule when the conditions next mentioned are obtained ; and, in like man-

ner, a course of repair free from disturbance and closely approximating in rapidity and perfection that of subcutaneous wounds is enjoyed by the last-mentioned wounds. The evidence which each of these groups of phenomena gives is harmonious and cumulative, and the only conclusion which is consistent with them is that the local suppurative and inflammatory, and the general infective disturbances which occur in wounds result from the vital activity of micro-organisms which have been introduced from without have found in the wound the conditions that favored their development and increase.

Other sources of irritation likewise exist and are capable of exciting suppuration and inflammation in wounds, but their effects are limited and transient in character, their action is easily recognizable and preventible, and their chief importance springs from the manner in which the conditions created by them favor the activity of micro-organisms.

CHAPTER IV.

ASEPSIS AND ANTISEPSIS—WOUND-CLEANLINESS.

The Scientific Basis of Wound-Treatment—Ptomaïnes—Sepsis—*Asepsis*—*Antisepsis*—*Cleanliness*—Primary Cleansing of a Wound—Drainage—Cleanliness of Adjacent Tissues—Cleanliness of Wound-Dressings—Air Purification—Antiseptic Sprays—Practice of Lister—Inefficiency of Antiseptic Sprays as Bactericides—Effects of Sprays—Dust-Laden Currents of Air to Be Avoided.

THE recognition of the activity of micro-organisms as the essential cause of disturbances of repair in wounds supplies a scientific basis for treatment and affords a definite principle by which to test methods of wound-treatment. It has been seen that it is not the organisms themselves that are the irritants that directly cause wound-disturbance, but the products that are formed in the course of their growth and multiplication, either directly secreted by themselves or formed by the decomposition of the substances on which they feed. These secondary products—ptomaïnes—are poisons or septic agents, and the results in general of their action upon the living tissues with which they come in contact constitute *sepsis.* Whatever tissue or wound-surface is uncontaminated by these ptomaïnes is in an *aseptic* condition, and whatever method or means antagonizes their production, or antidotes, restricts, or removes the results of their presence is an *antiseptic.*

The ideal treatment of a wound is that by which a perfectly aseptic condition should be obtained and preserved; where this is impracticable, the object of treatment becomes changed to the application of means to diminish the activity of the septic organisms, to secure the rapid removal of their products, and to increase the resisting power of the wounded tissues.

ASEPSIS.

Asepsis is present in wounds which are subcutaneous, and in wounds which unite by first intention. The defects of apposition, protection, or

nutrition which may prevent the accomplishment of union by first intention in a wound do not necessarily expose it to septic infection, but so much do they increase the difficulties of preserving the wound from such infection that the means of remedying these defects, and of securing union by first intention, when the conditions of the wound make it at all possible, become of the highest importance from the standpoint of the dangers of sepsis. The methods by which these defects are to be avoided belong to the practice of wound-treatment and will be reserved for consideration in that connection. Attention here must be restricted to general considerations bearing directly upon the prevention or correction of sepsis.

Asepsis may be preserved, if the wound is to be inflicted by the surgeon himself, by care in permitting access to the wound, at the time of its infliction and during its after-progress, of no object which is contaminated by septic agents. This involves purification of the air, instruments, dressings, and of the hands of the surgeon himself, and the most minute, exact, and persistent care throughout the course of the wound until its final cicatrization.

In wounds already septic, asepsis may be obtained by applying to their surfaces and recesses substances capable of destroying the septic germs and organisms present, and by using in their after-care dressings capable of excluding the further access of septic agents, or of preventing their development if their exclusion has been impossible.

ANTISEPSIS.

In wounds in which, for any reason—their location, their complications, the absence of necessary appliances, or whatever other cause—asepsis is impossible or impracticable, the effects of the septic agents that may be present may be modified and restrained, not only by the application to the wounds, as thoroughly as possible, of antiseptic substances, but also by the most perfect removal from the wound of devitalized substances and those prone to decomposition, which if left would be rich feeding-ground for micro-organisms, by the immediate removal of the noxious products of the septic condition as fast as produced, and by whatever agencies are capable of promoting general reparative energy or local resisting power in the wound-tissues.

The range covered by this enumeration of the means and methods of antagonizing septic conditions in wounds—antisepsis—is a wide one, and includes every form of wound-treatment which by experience has been found to favorably affect the healing of wounds. Those methods only, however, which in a special manner modify the vital activity of noxious micro-organisms, or nullify the results of such activity, can be considered in this connection. These methods will be considered in the following order:

First.—Those that are required to prevent the accumulation, or to ensure the removal of whatever substances might afford a pabulum favorable to the growth and increase of septic organisms; to facilitate the removal of septic products, if formed; and to prevent the introduction into the wound of any substance capable of inducing septic changes in it; these methods are embraced in the single idea, *cleanliness.*

Second.—The employment of substances as applications to wound-surfaces which are inimical to septic organisms, destroying them or restraining their growth—*antiseptics,* in the more restricted sense of the term.

CLEANLINESS.

That aspect of cleanliness which has to do with the prevention of the accumulation, and with the speedy removal of fermentable substances from a wound requires for its accomplishment, at the beginning of treatment, the removal of every substance which either itself should foster the growth of micro-organisms, or should provoke undue secretion from the wound, or that by the mechanical effect of its presence should delay union. The accomplishment of this end constitutes *Primary cleansing of the wound.* The full performance of this cleansing may, however, involve such increased hazards from the additional traumatism required for its accomplishment in some instances, that it may best be ignored, as in cases of bullets, needles and other bodies that have penetrated the tissues, and, becoming encysted, cease to irritate, and disturb but little the function of the parts in which they rest. Again, in cases in which an accumulated blood-clot would appear to violate the rule of cleanliness by its proneness to decomposition and by the mechanical effects of its presence, if it can be kept aseptic, or if efficient means of anti-

sepsis be available, it may, in cases of open wounds, with loss of substance so great as to prevent apposition of the divided surfaces, really facilitate repair by affording pabulum, support and protection to the forming granulation-tissue that gradually takes its place. In cases, also, in which rapid drying of a layer of blood-clot can be accomplished, the impermeable layer which it forms may constitute a perfect occlusive antiseptic dressing for the wound underneath it; but the doing up of a wound "in its own blood," to be successful, requires that the other possible demands of cleanliness that may be present or may arise in the wound be also regarded.

Of equal importance with the primary cleansing of the wound is the prevention of the accumulation within its cavity at any time in its after-history of wound-secretions and tissue-débris. The abundant serous exudation which occurs as the immediate result of the active hyperæmia provoked by a wound bathes in abundance the free surfaces of an open wound and gathers in its recesses, and when such wounds are closed externally, if exact apposition of its deeper parts be not also secured and maintained, separates its surfaces, and as long as it is retained, not only disturbs repair by the tension produced, but also offers the best of pabulum for promoting the vital activity of ferment-producing organisms. The prevention of such accumulation and retention becomes, therefore, of the highest importance in attempts to preserve a wound from disturbance.

Again, when suppuration has occurred in a wound, the pus brings into the wound the same elements of danger which attend the earlier serous exudation, with the added condition that septic products are already being mingled with the wound-secretions.

The spontaneous escape and draining away of all secretions and tissue-débris, as fast as exuded or separated, may be provided for either by the special arrangement of the wound-surfaces alone, or by the use of apparatus to drain them away. This portion of the requirements for securing cleanliness in wounds is termed *drainage*.

To so manage a wound as to prevent or to restrain the primary serous effusion will diminish the necessity for provisions for drainage. This can be accomplished in great measure in all wounds in which such apposition of the surfaces can be secured as to make union by first intention possible.

This should be the ideal to be striven for in all such cases. Its accomplishment means careful and perfect hæmostasis, careful primary cleansing, careful expression from the wound-cavities as its surfaces are being brought into apposition of all fluids present, perfect coaptation throughout all parts of the wound, deep and superficial, gentle compression and support and perfect protection, with infrequent dressings thereafter. With the perfect accomplishment of such precautions no accumulation of serum is possible, and provisions for drainage are unnecessary and objectionable. But whenever accurate coaptation is not secured, and a cavity exists in which fluid may accumulate, its drainage must be provided for.

The last requirement of wound-cleanliness, according to our analysis, is the prevention of access to the wound of any substance capable of inducing septic changes in it. From their relation to this requirement must be considered: 1, *Cleanliness of adjacent tissues;* 2, *cleanliness of wound-dressings;* and 3, *cleanliness of the air* that comes in contact with the wound.

Adjacent Tissues.—Perfect cleanliness requires not only that the tissues immediately adjacent to a wound be purified of gross impurities, but that they should especially be freed from any micro-organisms which might, by gaining access to the wound, make it septic.

Examination of the skin on regions much subjected to frictions and ablutions, as the hands, fronts of the thighs, arms, and forearms, shows micro-organisms so sparingly that epidermis removed from thence by scraping may often exhibit few or none. But in individuals who, from any cause, do not practise frequent ablutions, even in these regions they are usually found, while in not even the most cleanly person does the interdigital scurf of the toes fail to show abundance of both micrococci and bacteria. The scurf of the scalp contains mostly fungi and fungus spores, and is by no means rich in cocci or bacteria, while the secretion of the sebaceous glands shows both these forms to be present in abundance.

Micrococci are numerous in the cerumen of the ears and in the mucus of the nose, and there exceed in number the other forms of organisms. Bacilli, on the other hand, where micro-organisms are in great variety, the bacteria preponderate, and in the secretion from the skin of the axilla, which is usually sebaceous, obtained by gently compressing its tip,

almost the only forms met with are the bacteria, which are there, however, innumerable.

Sebum expressed from scrotal or perineal follicles shows multitudinous bacteria, slender rods, and micrococci; the anal region shows thick and slender bacilli, bacteria, and micrococci; while the fæces and interior of the bowels present the appearance of being entirely composed of infinite colonies of all varieties.

The author[1] on whose authority these statements are made adds:

"We need not even call into account the solids, fluids, and gases around us in our search for sources of infection when we possess in our own frames so abundant a supply. In relation to surgical questions, it is of use to know the extent and distribution of these germs on our persons, if our processes of disinfection are to be conducted aright. In operative procedures on the axilla and scrotum, for example, we ought to know that all our preliminary washings and disinfection are impotent to exterminate the micro-organisms that exist in the openings of the glands to a depth of one-fourth of an inch or even more. None of the proceedings in use in antiseptic surgery is of any avail to destroy them; they will continue to grow and reach the surface, and unless we maintain there a storehouse of some disinfectant material, frequently renewed, that will suffice to saturate all discharges and convert them into aseptic fluids, we shall assuredly find the organisms growing richly under our dressings."

The difficulty of securing the desired purification of the adjacent tissues becomes almost insuperable in wounds involving the mucous orifices of the body, so that unless they are of such a character that perfect apposition of the wound-surfaces can be secured, and immediate union by first intention obtained, they inevitably become septic wounds. Such wounds, therefore, cannot be treated by occlusive methods; efforts must be directed to antagonizing the inevitable sepsis and removing its products. But in all wounds, whether operative wounds at the hands of the surgeon or wounds accidentally inflicted, in which attempts at rendering and keeping them aseptic offer any hopes of success, all such attempts must include the purification of that portion of the skin which is covered in by

[1] Dr. Alex. Ogston: Micrococcus Poisoning. Journal of Anatomy and Physiology, Vol. XVI., p. 557.

the dressings, as much as the wound-surfaces themselves. Too great care in cleansing it cannot be taken.

WOUND-DRESSINGS.—In this class are to be included everything which necessarily is brought in contact with the wound in the attentions which it requires, as well as those substances which are applied more or less permanently to the wound to promote its healing. The persons of the surgeon and his assistants, the instruments and appliances of every kind that are used in or about the wound, the fluids that are used for irrigation, the drains, the ligatures, the sutures, the compresses, and protective appliances, must each equally comply with that degree of cleanliness which shall be necessary to prevent them from becoming the bearers of infection.

AIR PURIFICATION.

The more obvious sources of atmospheric impurity are overcrowding, deficient ventilation, the presence of suppurating wounds, the presence of infectious diseases, the proximity of walls, beds, or other absorbent materials charged with septic emanations, the vicinity of cesspools, sewer-basins, masses of putrefying material, or other foci of infection. The mention of these is sufficient to suggest the means of remedying them. No one of them should be overlooked in considering the cares to be rendered a wound. To the results which attend their neglect, attention has been called in a previous chapter.

The air of the country is more free from micro-organisms than is the air of a city, and that of the upper floor of a house than that of the lower floor. Facts that should be borne in mind when a choice as to where a wounded person should be treated is possible. After every ordinary precaution possible has been taken to secure a pure atmosphere by clean and pure surroundings, isolation, and abundant ventilation, what further means are necessary and available for securing absolute air-purity?

As has been stated in a previous chapter, putrescence invariably follows a sufficient exposure of putrescible fluid to the air, the length of the exposure needed being dependent upon the character of the local surroundings. Dr. Duncan, of Edinburgh,[1] found that in his laboratory a

[1] Germs and the Spray. Edinburgh Medical Journal, March, 1883, p. 778.

fluid presenting a surface of an inch and a quarter could be repeatedly exposed for nearly two hours without infection, and that to be reasonably certain of putrescence a surface of three inches and a quarter required an exposure of twenty minutes. The volumes of air that may be free from infective germs may be considerable in favorable localities, but, as there is no uniformity in the distribution of floating organisms, no given volume can be relied upon as absolutely pure.

ANTISEPTIC SPRAYS.—With the view of procuring absolute purity, at will, of all air coming in contact with a wound, Mr. Lister, in his earlier antiseptic technique, recommended to fill the atmosphere about a wound, as long as it was exposed, with a spray of a carbolic acid solution, believing that the acid had the property of killing whatever germs might be floating in the air thus charged.

The results of observations made by others did not confirm the supposed power of the carbolic acid spray to kill floating germs; particles of atmospheric dust, after having passed through a cloud of carbolic spray, were found to be still capable of exciting putrefaction in liquids upon which they lodge. Extended and repeated experiments definitely proved that, so far as the destruction of floating germs in the air is concerned, the spray was perfectly ineffectual. "When we consider the researches published by the German Health Bureau, it seems somewhat doubtful whether the carbolic acid spray ever killed a single healthy bacterium; the vitality of certain spores is certainly not thereby affected" (Belfield). It was realized that, instead of being beneficial, it is possible that a spray directed upon an open wound may be positively harmful by reason of the air-currents which it produces, by means of which floating particles in the air might be drawn into the cloud of spray and with it deposited in the wound. For these reasons, after a few years of vogue the carbolic spray was given up and the record of it remains now as one of the curiosities of surgery.

The observations of Miquel, at the Montsouris Observatory (see page 41), of the purification of the atmosphere from floating organisms produced by rain-storms, indicates how the spray may, nevertheless, be made a valuable agent in promoting the purity of the air in any given space. By means of the spray-producer it is possible to have a local rain-storm at any time, by means of which the floating matter in the air may be

mechanically precipitated. The temporary comparative purification thus secured would not be increased by the addition of a small proportion of any antiseptic substance to the material used for the spray, although such addition would not be objectionable. As the spray washes down upon the surfaces upon which it falls the floating matter which it carries with it, it should not be used so as to fall upon a wound. In the case of a surgical operation, or of the dressing of a wound, its use should be preliminary to the exposure of the wound. Although the air as a source of infection to a wound is of but little importance compared to the other sources of infection which have been mentioned, still it is not altogether insignificant. It will always be worth the attention of the surgeon to avoid, when possible, the making or dressing of a wound in localities or conditions in which dust-laden currents of air are present. It is especially desirable that the floor-surfaces of rooms in which operative work is being done should be kept moist, for thereby whatever floating particles that settle from the air are at once fixed against further flotation as long as the surface on which they have settled continues moist, and the walking about of persons in the room engaged in necessary duties or as spectators will not stir up from its rest any undesirable material. Particularly are to be avoided carpets and hanging tapestries in such rooms, since these fabrics are always rich depositories of dust, which issues in clouds whenever they are walked upon or agitated.

CHAPTER V.

WOUND-DISINFECTION—ANTISEPTICS.

Antiseptics in General—Comparative Bactericidal Strength of Various Agents—Strengths Required to Restrain Bacterial Multiplication—Mistakes Due to the Inhibiting Power of Minute Portions of Mercuric Bichloride—Inhibiting Power of Certain Powders—Local Effects of Antiseptics on the Tissues—Question as to Efficiency of Antiseptics in Infected Wounds—Observations of Halsted, Kawalewsky, Schimmelbusch, Henle and Messner—Conditions Presented by Suppurating Granulating Surfaces—General Toxic Effects—*Special Antiseptics*—Carbolic Acid, Creolin and Lysol—Salicylic Acid—Boracic Acid—Corrosive Sublimate—Iodine and Iodoform—Iodine Compounds, Aristol, Airol, Iodol, Nosophen—Salts of Bismuth, the Subnitrate, Subgallate and Subiodide—Zinc Compounds, Oxide, Chloride, Mercuric Cyanide, Sulphocarbolate and Others—Formaldehyde, Formalin—Heat, Fractional Sterilization, Thermal Death-Point of Pyogenic Micro-Organisms.

In addition to the resources of cleanliness for preserving wounds from becoming the seat of the vital activity of micro-organisms, there still remains to the surgeons the employment of direct applications to the wound-surfaces of substances which have the power either to destroy them outright or to restrain their growth. In general parlance, the application of the term *antiseptics* is restricted to these substances.

The possibility of obtaining antiseptic results in a wound by agents that simply restrain the growth of septic organisms, as well as by those that destroy them, is a matter of great practical importance, for it has increased the number of substances available for antisepsis, and since the preventive effects of many agents can be accomplished by much smaller amounts than their destructive effects, it has been found possible to obtain their antiseptic effects with less local irritation of the wound itself and less liability of danger from absorption of poisonous quantities of the agent into the blood.[1]

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[1] This inhibitory action of certain agents is similar to the effect upon certain processes of vegetable life exhibited by anæsthetics. "The addition of

In estimating the usefulness of any agent as an antiseptic application in the treatment of wounds, three things have to be taken into consideration:

1. Its power as a bactericide or as a restrainer of bacterial multiplication.

2. Its immediate local effect on the wound surfaces—neutral, irritant or caustic.

3. Its remote constitutional effect when absorbed into the general circulation.

Some general considerations under each of these should receive attention before taking up individual antiseptics.

1. *What amounts of the various antiseptic agents are necessary to introduce into a wound to secure the destruction or resist the multiplication of whatever septic organisms may have gained access to it?*

The fact that bacteria of different species manifest different degrees of vital resistance to chemical reagents, and that differences in the physical condition of the same species of bacteria at different times likewise cause variations in the effects produced by applications made to them, must always be borne in mind in the clinical application of experimental researches as affecting the precise strength of an agent needed to antagonize possible septic organisms.

Experiments by Sternberg (1883)[1] gave the following amounts as the strengths required for certain reagents, enumerated, to destroy the vitality, or to prevent the development of the micrococci of pus. The fluid containing the micro-organisms, with proper precautions to guard

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ether to an infusion containing yeast, at once arrests the process of fermentation. On removal of the anæsthetic, by evaporation or by filtration, the activity of the yeast fungus is renewed, and fermentation is again resumed. If an aquatic plant be placed in a watery solution of ether or chloroform, its absorption of carbonic anhydride and its exhalation of oxygen cease. The plant does not die; it merely sleeps. On replacing it in pure water, its natural respiration is immediately resumed. The germination of seeds may also in a similar manner be arrested by surrounding them with an anæsthetic atmosphere" (Lyman: Anæsthetics and Anæsthesia; The International Encyclopædia of Surgery, Vol. I., p. 109).

[1] Experiments to determine the Germicide Value of certain Therapeutic Agents. American Journal of the Medical Sciences, April, 1883, p. 335.

against errors, was subjected by this experimenter to the test liquids for a space of two hours. The following table exhibits the strengths needed to destroy the organisms; it is of value, just as much now as fifteen years ago, simply as showing the effect of certain chemical disinfectants upon the most common wound-disturbing organism. The practical application has found its place rather in the preliminary disinfection of materials likely to come in contact with wounds in the course of formal surgical operations than in applications to wounds themselves:

TABLE OF BACTERICIDAL STRENGTHS.

Reagent.	Efficient in the proportion of one part in
Mercuric bichloride	20,000
Potassium permanganate	833
Iodine	500
Creosote	200
Sulphuric acid	200
Carbolic acid	100
Hydrochloric acid	100
Zinc chloride	50
Tinctura ferri chloridi	25
Salicylic acid dissolved by sodium borate	25
Citric acid	8
Chloral hydrate	5

The following-named reagents failed in the proportions given below, which were as far as the experiments were conducted with them:

	Failed in the proportion of
Fowler's solution (arsenite of potassa)	40 per cent.
Sodium hyposulphite	32 "
Sodium sulphite (exsiccated)	10 "
Ferric sulphate (saturated solution)	16 "
Potassium iodide	8 "
Liquor zinci chloridi	8 "
Zinc sulphate	20 "
Boracic acid (saturated solution)	4 "
Sodium borate (saturated solution)	4 "
Sodium salicylate	4 "

Similar experiments made with the micrococcus of gonorrhœa, the micrococcus of septicæmia in the rabbit, the bacterium termo, and upon the organisms developing in broken-down beef-tea which had been freely exposed to the air, showed that in general those reagents which destroyed the vitality of the micrococcus from pus are equally efficient when a different micro-organism is used. The most uniform power was displayed in all the cases by mercuric bichloride and by iodine, which the author present as bactericidal agents of the highest value, giving as the proportion in which they would certainly be efficient as one part in five thousand for mercuric bichloride, and one part in two hundred for iodine.

Experiments made to determine the minimum quantity of the reagents named required to prevent the development of the various micro-organisms gave results which also were found to be pretty uniform for the three different organisms. As will be seen in the subjoined table, boracic acid, sodium biborate and salicylic acid dissolved by means of sodium biborate, though they had not been found to possess any bactericidal value, even in four per cent. solutions, proved to be potent in preventing the development of septic organisms. This power is more marked in the case of the bacterium termo, a putrefactive organism, than in that of the pyogenic micrococci.

The following table shows the minimum quantity required to prevent the development of the pyogenic micrococci:

TABLE OF STRENGTHS REQUIRED TO RESTRAIN BACTERIAL MULTIPLICATION.

Reagent.	Efficient in the proportion of one part to
Mercuric bichloride	35,000
Iodine	4,000
Sulphuric acid	1,800
Carbolic acid	500
Salicylic acid and sodium biborate, equal parts	200
Boracic acid	200
Ferric sulphate	200
Sodium biborate	100
Alcohol	10

Comparison of the two tables shows that the more potent bactericides

have the power of restricting multiplication in quantities considerably less than are required to destroy vitality. In the case of iodine, the difference is eightfold; in that of carbolic acid, fivefold; in that of sulphuric acid, fourfold, etc.

The experiments of Lübbert (1886) upon the influence of antiseptic agents upon the yellow pus coccus implanted on nutrient gelatine gave similar general results, although the special inhibitory value of particular agents was not the same. In the order of efficiency the proportion of agents required to prevent development was determined by him to be as follows: Mercuric bichloride, 1:81,400; thymol, 1:11,000; iodine dissolved in potassium iodide, 1:1,100; carbolic acid, 1:814; salicylic acid, 1:655; oxalic acid, 1:433; boracic acid, 1:327.

After the observations of Geppert, published in 1889, it was recognized that this power of minute quantities of mercuric bichloride to restrain the development of micro-organisms was so great that by the neglect of previous experimenters to use efficient means to decompose every trace of the sublimate possibly attached to the substance experimented with, their conclusions as to absolute bactericidal strengths were invalidated. By the addition of ammonium sulphide to precipitate every trace of sublimate adherent to or in combination with materials tested, it was found that many such, which under the tests previously in vogue had been apparently sterile, still contained living bacteria. The practical importance of the recognition of this fact in dealing with wounds arises from the possibility of bringing into contact with wounds materials supposedly adequately disinfected, but really only in that state in which bacterial activity is inhibited. The inhibiting agent is quickly neutralized by combination with the albuminous secretions and the activity of the organisms no longer restrained. Abbott, in 1891, showed that the yellow pus staphylococci were still active after exposure for five minutes to a 1-1000 solution of corrosive sublimate, and that after exposures of ten, twenty, thirty and forty minutes, even sixty minutes, some of the organisms still remained alive. Since some of the organisms were killed by the shorter exposures and others evidently succumbed only gradually, and if removed from the influence of the bactericide still possessed power of reproduction, though very much enfeebled, he argued the existence of varied degrees of vitality among such

organisms. He concluded also that the reaction which took place between the antiseptic agent and the micro-organism was a definite chemical one between the protoplasm of the individual bacterium and the sublimate in solution, so that even under the most favorable conditions a given amount of sublimate could have the property of rendering inert only a certain number of individual organisms.

In addition to these soluble agents, marked antiseptic power attaches to many substances which are insoluble or comparatively so. These include iodoform, naphthalin, zinc oxide, bismuth subcarbonate, subnitrate, subiodide and subgallate, aristol, airol, iodol, nosophen and other similar compounds. The common property of this group of agents is the inhibition by their presence of bacterial growth and multiplication. To some of them attaches also a chemotactic power; that is to say, the power to stimulate the accumulation of living energetic cells in the wound-surfaces and borders. The effect of this is to strengthen the local resisting power of the tissues and to favor rapid repair.

2. *The effect which a substance introduced into a wound as an antiseptic may have on the exposed surfaces of the wound must be taken into consideration in choosing for use, as well as its effect upon the organism supposed to be present.*

A pronounced irritating or caustic effect may render an agent unfit for use upon living tissues. Even if but slightly irritating, the increased serous flow, which its application may provoke, may seriously embarrass the attempt to prevent the development of septic conditions in it. On the other hand, the chemotactic influence of certain agents, which has already been referred to in the preceding paragraph, may be sufficient to counteract the irritant or caustic effects to such a degree as to render their use of positive value. In this connection, the experiments of Kawalewsky[1] are instructive. This author attempted to solve the problem as to whether the action of certain antiseptics was due to their bactericidal properties or to their producing a local leucocytosis. The substances experimented with were iodine, potassium iodide, mercuric bichloride and zinc chloride. His conclusion was that each of these chemicals had a positive chemotactic action, producing a local leucocytosis, and

[1] Inaugural Dissertation, Berne, 1896.

that their value as antiseptics was as much through this chemotactic property as by their bactericidal action.

The property of producing upon wound-surfaces a thin film of coagulated albumen uncongenial to the growth of germs, as a protection of the surfaces covered by it, and which, by pressure, tends to restrain effusion, has extended greatly the usefulness of so feeble an antiseptic as chloride of zinc; while the freedom from irritation of iodoform and bismuth powder, and their properties of absorbing moisture and exercising compression upon the surfaces to which they are applied, thus restraining secretion, add greatly to their antiseptic influence.

The question of the real value of the introduction of antiseptic agents into infected wounds has been a matter of experimental investigation and of dispute. Halsted had shown that a distinct line of superficial necrosis could be demonstrated under the microscope upon the walls of fresh wounds that had been irrigated with a solution of mercuric bichloride as weak as one to ten thousand, and the conclusion had been drawn that by increasing the amount of devitalized tissue to be disposed of, such an irrigation was positively harmful, the more so since the work of Geppert had proved that many organisms would survive a long immersion in a much stronger solution. The later observations of Kawalewsky have introduced a new element into the discussion and tend to confirm the earlier opinions as to the antiseptic efficiency of sublimate solutions in wounds. Schimmelbusch, however, in 1893 and 1894, in papers read before the Congresses of German Surgeons of those years, claimed that it was impossible to disinfect septic wounds by the application of antiseptic agents to them on account of the rapidity with which micro-organisms may enter the tissue spaces and be conveyed beyond the reach of the disinfectants. In a large number of experiments with various organisms it was shown that in five minutes after bacteria are introduced into a fresh wound they can be found in the internal organs. But Henle, in another paper at the same congress, pointed out that experiments with pure cultures of highly virulent organisms in large quantities did not represent clinical conditions. Most organisms, even those pathogenic to man, find such a resistance to them in the living tissues that they can multiply only in localities in which a diminished resisting power has been created. A wound is to a greater or lesser degree such a *locus minoris resistentiæ*,

but the extension of ordinary infective organisms beyond the immediate confines of the wound is exceptional and takes place only after some time and in conditions specially favorable to bacterial activity. Thus in wounds in rabbits' ears, experimentally infected with pyogenic streptococci, migration of the organisms into the lymph-channels could be detected only after the lapse of six hours, and irrigations of the wounds with 1:1000 sublimate solution or 4 per cent. carbolic acid solution, done two hours after the infection, secured efficient disinfection, and when employed six hours after, the severity of the infection was greatly diminished. These conclusions were further confirmed by the experiments of Messner. Twenty rabbits were subjected to identical wounds, which were all infected with a like amount of pus or bouillon pus culture. At the end of a given time, as late as eighteen hours after the infection in some instances, in one-half of the animals the wounds were reopened, washed out with sterilized normal salt solution and again bandaged up with a dry aseptic dressing; in the other half the wounds were washed out with a warm 3 per cent. lysol or carbolic solution, and loosely packed for twelve hours with a wet carbolic gauze and covered with a wet carbolic dressing. After the twelve hours a dry aseptic dressing was applied. As a result, of the first set, all but one of the ten died in from eight to fourteen days of extensive phlegmonous suppuration; while of the second set all but one recovered. In two of these antiseptically-treated animals the wounds healed without suppuration; in the others moderate suppuration occurred, entirely limited to a narrow area immediately about the wound. In one case only an extensive and fatal phlegmonous process developed. A marked difference was also found to exist in the comparative virulence of the pus produced in the two sets of wounds. Inoculations of other animals made with pus from these wounds revealed so high a degree of virulence in the pus from the aseptically-treated wounds that all the animals inoculated with it perished in from twenty-four to forty-eight hours; and in the pus from the antiseptically-treated wounds that suppurated, so diminished a virulence that of those inoculated with it all lived.

In order to nullify the possible effects of septic contamination of a wound it appears, therefore, unquestionable that positive assistance may be derived from flushing it with antiseptic agents, even many hours after

the infection has occurred. For this purpose it is evident that it is not necessary that solutions of such strength should be used as would be required to kill outright all the organisms present; much more dilute solutions are efficient to destroy many and to attenuate and restrain the development of what remains, and to so stimulate the resisting power of the already invaded tissue that further invasion is prevented and the damage already done is quickly recovered from. This is the essential principle of the antiseptic treatment of wounds, and its preeminent value was demonstrated on the largest possible scale clinically by the marvelous change in the progress of the healing of wounds which followed at once and everywhere that the earlier antiseptic methods of wound-treatment were adopted, notwithstanding the crudeness and positive inefficiency of many of the details of antisepsis as at first practised.

In dealing with wounds or cavities that are already the seat of a suppurating process of some duration, as abscesses, suppurating phlegmons, empyema of the thorax, osteomyelitis, etc., a different condition of affairs exists from that which fresh and recently-infected wounds present. An abundant leucocytosis has infiltrated the tissues about the focus of infection and established a barrier to the further spread of the infection, and it is only required that a free vent should be given to the pent-up discharges, and to all further secretions as fast as formed, to insure that a victory of the accumulated active cells over the local infection should follow very speedily in most instances, without the assistance of any disinfecting agents from without. Indeed, active efforts at disinfection may be positively disadvantageous to the degree that they abrade the granulating surfaces or break up adhesions already formed.

3. *The possibility of the production of general toxic symptoms by absorption of the agents used as local antiseptic applications is always to be borne in mind as a consideration checking the unlimited use of these agents.*

The amount of danger attending the use of particular agents will be considered in connection with each. In general, however, it may be stated that the larger the surface exposed to the action of the agent, and the more prolonged the exposure, the greater the danger of absorption in toxic quantities becomes.

The special properties of individual antiseptics will now be consid-

ered, including, however, only such as have been found by experience to be of special value as wound applications. They will be taken up in the following order:

Carbolic Acid, Salicylic Acid, Boracic Acid, Corrosive Sublimate, Iodine and Iodoform and its substitutes (Aristol, Airol, Iodol, Nosophen, etc.), the Bismuth Salts, Zinc Compounds, Formaldehyde, Heat.

CARBOLIC ACID.

The use of carbolic acid as an antiseptic owes its introduction to Lemaire, of France, who published a work entitled "De l'acide phénique" in 1863. Lemaire was the first to use carbolic acid, and was the first to realize the truth of the germ theory as applied to wounds.[1] The first interest in the use of this agent had in great degree subsided, inasmuch as the use of it, applied in the way recommended by Lemaire, had failed to give satisfactory results, when it was taken up by Mr. Lister, in 1866, in his wards in the Royal Infirmary of Glasgow, and by him brought through various modifications of use until a complete system of wound-dressing, based upon its antiseptic properties, known as the Listerian method, was ultimately elaborated.

A more accurate knowledge of the character of the agencies which are capable of disturbing the repair of wounds, and the power of other agents to equally or more certainly counteract them, has caused carbolic acid to become much less used than at one period. Still, to carbolic acid itself will always attach the interest which comes from having been the agent through which the possibilities of antiseptics in the treatment of wounds were first demonstrated; and to Mr. Lister will ever remain the credit of having first appreciated the full relations of sepsis to wound-disturbances, and of having devised a method by which septic infection in a wound was certainly guarded against.

Carbolic acid is a product of the destructive distillation of coal. Pure carbolic acid is absolute phenol, C_6H_6O. It is supplied as a pinkish crystalline mass, readily soluble in fifteen parts of water at the ordinary temperature. When subjected to slight heat it liquefies, and may be made permanently liquid by adding to it five per cent. of water.

[1] Cheyne: Antiseptic Surgery, p. 356.

The ordinary commercial acid contains an homologous substance, cresol, which does not crystallize, and, though very deliquescent, does not dissolve readily in water. It has equal antiseptic properties, but is more irritating and causes numbness and tingling of the skin in a much greater degree than the pure acid does. One part of the ordinary commercial acid will dissolve with some difficulty in twenty parts of water.

Carbolic acid is freely soluble in glycerine and in alcohol, and readily blends with oil in any proportion. The best way of preparing either oily or watery mixtures is to first put a few ounces of oil or water into the jar or bottle, and then add the full quantity of acid, previously melted by heat. Mix the two thoroughly, and afterward add the remainder of the oil or water, otherwise it is difficult to properly blend the oil or water with the acid.

The watery solutions used by Lister were of two strengths, one being five per cent., or 1 part in 20, and the other two and a half per cent., or 1 part in 40. The five per cent. solution was employed for purifying the hands of the surgeon and his assistants before and during an operation; also to disinfect the surface of that region of the body where the operation was about to be performed, and all parts which would be included in the subsequent dressing—also for supplying the steam spray. In a solution of this strength sponges were preserved, also silk and drainage-tubes.

The 1 in 40 solution was used for the purpose of irrigating a wound, washing the sponges used during an operation, soaking the gauze which was first applied to the surface, and for filling the tray in which the instruments required were placed. Glycerine in equal proportion to the carbolic acid may be added with advantage to the watery solution. It helps to prevent the too rapid volatilization of the acid, and counteracts to some extent its irritating properties.

Carbolic oil consisted of a mixture of carbolic acid and olive oil in various proportions. The 1 to 5 oil was most used as the menstruum in which catgut was permanently preserved. It was soon shown by Koch, however, that solutions of carbolic acid in oil or alcohol are absolutely inert in respect to their action on bacteric life, either on the spores or the fully-developed organisms. Anthrax spores introduced into oily solutions of carbolic acid, of thymol, and of salicylic acid, in each at the end

of three months were still found capable of development. Koch, however, remarks that "when the oily solution came in contact with substances containing water, as, for instance, the tissues of the human body in wounds, etc., then it undoubtedly gave up part of the acid to these, and in this way an antiseptic effect would be produced. In all cases, however, in which dry substances, such as silk, catgut, instruments, etc., have carbolic oil applied to them, not the least antiseptic effect is to be expected even upon the most vulnerable micro-organisms."

The possibility of catgut having been made from the intestines of anthracized sheep renders special caution in its perfect disinfection necessary. Zweifel, of Erlangen, Kocher, of Berne, Volkmann, of Halle, and Owens, of Chicago, have already reported cases of anthrax-infection of wounds by means of catgut.

The use of gauze and other materials impregnated with carbolic acid as wound dressings formed an important part of the original Listerian technique. It was early recognized that only such materials as had been freshly charged with the drug were to be relied upon, owing to the volatility of the acid, which caused a rapid deterioration in the antiseptic strength of carbolized dressings.

Advantages of Carbolic Acid as an Antiseptic.—The properties of carbolic acid which commend it for use as an antiseptic are:

1. Its *reliability*. Comparatively weak aqueous solutions, 1 to 20 and 1 to 40, are efficient for the destruction of all micro-organisms except the spores of such resistant organisms as the bacillus of anthrax, which need not be ordinarily considered in connection with wounds, while much weaker solutions suffice to prevent development as long as the reagent continues to be present.

2. Its *diffusibility*. The miscibility of the reagent-solutions with wound-secretions, and the absence of any escharotic or coagulating effect from the dilute solutions used, favor its penetration into all parts of whatever wound may be treated with it, whereby complete and thorough disinfection of all parts of the wound is favored.

Disadvantages.—1. The *local irritation* which it excites. Carbolic acid, when brought in contact with albuminous fluids, as serum or pus, forms a compound with the albumen—phenol-albuminate—so that its addition in larger quantities and in greater strength is necessary to

secure complete disinfection of wounds, if they have already become septic. The irritation produced by the use of solutions of the required strength, 1 to 20 to 1 to 40, increases capillary oozing, and excites an excessive and prolonged serous flow from the wound surfaces. In this respect its use violates one of the most important indications of wound-treatment, to diminish the amount of putrescible material in a wound. To overcome this, greater complexity of drainage and of external dressings to a wound are demanded, and the most watchful care against the possible entrance of septic organisms is rendered necessary. Eczema and erythema of the skin covered by the carbolic dressings is not an infrequent effect. It benumbs the skin and is followed by general branny exfoliation of the superficial layers of epidermis. This is particularly likely to be disagreeably marked upon the hands of the surgeon using it. Superficial necrosis of skin and connective tissue has frequently followed the long-continued use of quite dilute solutions.

2. Its *volatility* lessens its usefulness as an agent to secure permanent antisepsis, making frequent renewal of the dressings necessary, which renewals violate another fundamental principle of wound-treatment, that of rest. Unless the dressings are frequently changed, organisms speedily appear in the discharges that accumulate under the dressings.[1] The necessity of restraining the volatilization of this antiseptic by enveloping the dressings charged with it in an impermeable material—macintosh—keeps the parts thus confined in a state of moist warmth, which promotes exudation and favors decomposition by maintaining a condition favorable for the occurrence of putrefaction as soon as the antiseptic is sufficiently exhausted. By keeping the skin underneath it moistened with retained secretions it establishes also a favorable channel for the introduction of organisms from without. Its volatility makes absorbent dressing materials that have been charged with it entirely unreliable for antiseptic dressings after they have been prepared for more than a few days. A surgeon in ordinary practice is thus prevented from keeping it in stock for emergencies.

3. Its *toxic* qualities. The absorption of carbolic acid in poisonous quantities is more frequently observed when large cavities or extensive

[1] Cheyne: Antiseptic Surgery, p. 238 *et seq.*

wounds are washed out or are exposed to the action of the reagent under a pressure that favors its absorption. Some persons seem peculiarly susceptible to the influence of carbolic acid, and in them quite a small quantity will suffice to excite symptoms of poisoning. Children and women seem more especially liable to its noxious influence. Many fatal cases of poisoning by absorption of carbolic acid, when used as an antiseptic application, have been recorded. The severe cases are characterized by symptoms of profound collapse, which speedily terminates in death by failure of the respiration. In the less severe cases gastric derangements first appear, as loss of appetite, frequent nausea, or incessant vomiting; there is an increase, often enormous, in the secretion of saliva. More or less stupor or giddiness, noises in the head, or other signs of cerebral disturbance. The secretion of urine is diminished, and very often becomes of a dark olive-green color. It may be passed in this condition, or may become dark only after standing for some time. There is, however, no direct relation between the toxic effects of the carbolic acid and the amount of the discoloration. It is met with when there are no other symptoms; or the urine may be clear, while other well-marked signs of carbolic-acid poisoning are present. Abandonment of the use of the acid is at once required when toxic symptoms arise. Little benefit is to be expected from any other treatment.

In Mr. Lister's practice, according to Cheyne, carbolic-acid poisoning was a thing of very rare occurrence. The reason given for this immunity is that Mr. Lister brought carbolic acid as little as possible in contact with wounds, applying it freely to everything which might come in contact with the wound, rather than to the wound itself. He did not irrigate wounds, nor inject them, nor even wash away the blood and dirt from the line of incision.

The importance of the disadvantages that attend the use of carbolic acid in the treatment of wounds is so great that, with the increasing knowledge of the requirements for preventing the septic infection of wounds, and of the value of other agents for that purpose, its use has become very much circumscribed. Only, perhaps, for use in the antiseptic bath for the immersion of metallic instruments can it not now be replaced by less objectionable substances.

As a substitute for carbolic acid certain other products of coal-tar

distillation, *Creolin,* and Cresol, mixed with potash soap *(Lysol),* have been used. These substances have marked antiseptic power, do not produce so much local irritation, and are much less toxic. They form milky emulsions when mixed with water, and have been used in such emulsions of from two to five per cent strength.

SALICYLIC ACID.

The phenol derivative, salicylic acid, was one of the earliest agents largely used as a substitute for carbolic acid. By the action of carbolic acid on phenol sodium, sodium salicylate was produced, and by the decomposition of the latter by hydrochloric acid, the free salicylic acid was secured, an odorless, nearly tasteless, unirritating, comparatively insoluble, non-poisonous agent, with marked antiseptic properties. Its use as an antiseptic was taken up and advocated especially by Thiersch, of Leipzig, who used it both as a powder and in solution. Its combination with boracic acid in solution has since generally been known as *Thiersch's Solution,* which contained three parts of salicylic acid and thirty parts of boracic acid to one thousand parts of water. Wound surfaces were not irritated by it, nor was the granulating process disturbed. Further culture-tests showed, however, that it had very feeble power in destroying or even restraining the growth of pyogenic organisms, although it was more efficient in its effects upon the saprophytic organisms of fermentation and decomposition. It has more of a historical than a practical interest in the matter of wound-antisepsis. In the aseptic technique of the present day the solution of Thiersch, however, still finds a place as a preliminary application to the skin of a region to be disinfected, by reason of the property of the acid to soften epidermal scales and thus to make more easy and certain their thorough removal by later scrubbings and the deeper penetration of a more efficient bactericide.

BORACIC ACID.

The claims that were made for boracic acid as a reliable antiseptic agent were early shown to have little actual foundation by such observations as those of Sternberg and Lübbert. A saturated solution of the acid has no bactericidal property and but feeble inhibiting power. It is, however, unirritating and non-toxic, and may be used in unlimited quantities wherever the presence of a bland, feebly-inhibiting agent is

indicated, as in the dressing of extensive burns, or as an ingredient of a protective ointment to be applied to a granulating surface.

CORROSIVE SUBLIMATE.

The use of corrosive sublimate (mercuric bichloride) in the treatment of wounds dates from the publication, in 1881, of the researches of Koch upon Disinfection.[1] The anti-putrefactive properties of this salt had long been a matter of common knowledge, but its employment by surgeons had been prevented by fears of its toxic effect through absorption. The observations of Koch, however, upon its effects upon the bacilli of anthrax, the spores of which, though they were unaffected by other antiseptics, were reported by him to have been killed in a few minutes in a solution of corrosive sublimate, 1:1000, and to have been prevented from developing by a solution of 1:5000, inspired surgeons to a trial of this agent, the results of which were most satisfactory. The healing of wounds after disinfection by the sublimate and under dressings impregnated with it was accomplished with a certainty previously unknown. The weakness of the solutions required was such that it was found that extensive wounds could be irrigated with them for long periods of time without serious danger of intoxication. Wound surfaces flushed by it were not provoked to profuse serous discharges, nor did renewed or increased capillary oozing follow its application. It was free from odor; owing to the diminished quantity of wound secretion, the changes of dressings required were more rare, and much more frequently provisions for drainage could be omitted altogether. In some persons, however, the ordinary solutions irritated the skin and in some cases a skin inflammation was provoked, characterized by a pustular folliculitis. For some years the practice prevailed extensively of flushing all wounds freely with a sublimate solution and of covering wounds with absorbent dressings moistened with it. Occasional instances of serious, even fatal, poisoning from absorption of the salt were met with, but they were very rare, and the generally favorable course of wounds so treated was most satisfactory. As, however, the sources of infection of wounds became better understood, and there was elaborated

[1] Mittheilungen aus dem Kaiserlichen Gesundheitsamte, 1881.

a more reliable technique for the prevention of the access of micro-organisms to wounds, the necessity of the hitherto practised antiseptic flushings of fresh wounds gradually became recognized as non-existent, and at the present date, 1898, the use of sublimate solutions for such purposes has been almost entirely abandoned. Its value even for the disinfection of suppurating wounds is questioned. It still remains, however, as the most reliable agent available for the disinfection of fresh wounds that are known or presumed to be infected. For this purpose 1:5000 aqueous solutions are used. It is much used also in the strength of 1:1000 or 1:2000 for the disinfection of the skin in regions that are to be operated upon, and for the disinfection of the hands of surgeons and assistants.

IODINE AND IODOFORM.

IODINE has been long in use as a topical application to wounds. In 1854 it was praised by Duroy;[1] in 1871, Richardson advocated its use as a most valuable agent in the treatment of wounds, alleging that it deodorizes, controls discharge, destroys decomposing products, and does no systemtic injury.[2] Bryant, writing in 1882,[3] said that for purifying wound-surfaces he had employed for years an iodine lotion made by adding twenty drops of the tincture to the ounce of water. In his practice a sponge wrung out of this lotion (made with hot water), and held to a wound for a minute, sufficed usually to check all oozing of blood, and tended more than anything else, except prolonged exposure to the atmosphere, to the formation of that glaze upon the surface of the wound which he had found to conduce much to satisfactory repair.

The antiseptic properties of iodine, according to Sternberg's experiments, are many fold greater than those of carbolic acid—as a bactericide five times, and as a restrainer of bacterial growth eight times as great—but they have attracted general attention only since the intro-

[1] *Expériences et Considérations nouvelles pour servir à l'histoire de l'iode. Union Médicale*, Paris, T. viii., 1857.

[2] On the Science and Art of Healing Wounds. Transactions St. Andrew's Medical Graduates Association, 1871, v., p. 49.

[3] International Encyclopædia of Surgery, 1882, ii., p. 27. Article on Wounds.

duction into use, as an antiseptic, of its compound, iodoform, the teriodide of formyl, C_2HI_3, which contains ninety-six per cent. of iodine.

Iodoform owes its introduction into general use as an antiseptic agent especially to Mosetig-Moorhof, of Vienna, who advocated its use first in a series of articles published in the *Wiener Medicinische Wochenschrift* in 1880 and 1881, and later in a clinical lecture published in Volkmann's series.

The advantages apparently possessed by iodoform caused its immediate and extensive adoption: by it was introduced a new method of antiseptic dressing, the *dry-powder* dressing, which more perfectly met the requirements of a wound-dressing, in many cases, than any method that had preceded it. It restrained wound-secretion and thus diminished the amount of pabulum for bacterial growth in a wound; it did not irritate the wound: it was used both as an application to the wound-surfaces and as an external, antiseptic, protective dressing; its decomposition or its volatilization was so slow that the frequency of the dressings required was greatly lessened.

In open wounds the cavities, after having been lightly sprinkled with the powder, were filled with gauze charged with iodoform. Such wounds were found to remain free from pain, the scanty discharge which took place was serous in character, the surrounding integument remained free from inflammatory swelling, and the process of granulation proceeded rapidly and without interruption. When, however, the reparative process was far advanced, ultimate cicatrization was hastened by the use of some other agent. Experience showed also that iodoform was especially adapted for use in the treatment of wounds involving the mouth or anal region, in which cases plugging the wound with iodoform-gauze sufficed to keep it from serious septic disturbance. Frequent removal of the dressing even was unnecessary.

The odor and the toxic qualities of the drug were at first the chief disadvantages that seemed to limit its use.

Its *odor* is pervasive and lasting, and quite disagreeable to most persons. Musk, Peruvian balsam, various essential oils, as bergamot, clove, and peppermint, have been proposed as corrigents. Mosetig-Moorhof originally used Tonquin bean for the purpose. Schork says that if 0.05 gramme of carbolic acid be rubbed up with 10 grammes of iodo-

form, and 2 drops of oil of peppermint be added, the unpleasant odor is entirely covered and is not again developed even under a high temperature.

Its *toxic qualities* early claimed attention on account of the great freedom with which the earlier employment of the agent was characterized. Various degrees of toxic action were recorded, and experience demonstrated that its use must be guarded with certain cautions, if risks of fatal consequences were to be avoided. It acts by absorption into the general circulation of poisonous quantities from the wound-surfaces. Poisonous doses cause rapid and feeble heart-action, coma, and paralysis of the organs of respiration. Autopsies have demonstrated in such cases the lesions of meningitis and fatty degenerations of the heart, liver, and kidneys. But the most remarkable manifestations of poisoning in the human subject are due to perverted cerebral action, taking the form of mental derangement. Every degree of intoxication has been observed, from simple exaggeration of nervous excitability to the condition of acute mania. In the lighter cases patients are restless and uncomfortable, complaining of headache, loss of appetite, wakefulness, and the constant taste of iodoform. Such symptoms often, but not always, precede those which are met with in bad cases, which are nearly identical with the symptoms of delirium tremens. From such a condition many persons recover, while others die, often suddenly, from exhaustion or coma. No antidote to the poison has been discovered, and the only treatment of any avail is that of preventing further intoxication, and supporting the patient's vital powers by alcoholic stimulants until the crisis is past. The susceptibility to its action appears to vary greatly in different cases. Old persons are especially liable to suffer from iodoform-poisoning. It should be employed with great caution, and in such a manner that it can be readily removed from the wound in case symptoms of poisoning should supervene.

It early became apparent that iodoform dressings gave but little security against erysipelas, and in 1887 Heyn and Rovsing[1] demonstrated that pyogenic organisms could preserve their vitality after being kept for

[1] **Das Iodoform als Antisepticum.** *Fortshritte der Medicin*, 1887, 5, 33.

many days covered by iodoform in powder or in oleaginous solution, and that iodoform could even be a vehicle for carrying infection. Further research by many investigators has confirmed these statements, and it is settled that although iodoform has the power to inhibit the growth of some organisms, it has but feeble power over the staphylococci and streptococci of suppuration. Nevertheless its clinical value to prevent suppuration and to minify septic disturbances in wounds was unquestionable. The theory that the value of iodoform rested in a power to neutralize the products of bacterial growth, and thus to eliminate from an infected wound the presence of the chief agent that rendered possible the continued activity of bacterial life, was confirmed, particularly by the work of Behring,[1] who proved that in the presence of pus a chemical reaction occurred between the ptomaines present and the iodoform, whereby the iodoform was decomposed, iodine set free, and the ptomaines themselves destroyed. The final outcome of the study of the properties of iodoform has been thus to greatly restrict its use, but nevertheless to establish it as an antiseptic agent of the greatest value in wounds in which an active bacterial growth was present or unavoidable, as in all extensive open wounds, in wounds involving mucous membranes and the excretory outlets of the body, and in wounds communicating with septic cavities, as in necrotomies and abscesses. It diminishes secretion, decomposes ptomaines and stimulates leucocytosis, and, when itself decomposed, liberates the germicidal iodine. It possesses but little germicidal power in itself, and should therefore always be sterilized by an immersion in a solution of sublimate or by exposure to heat before being used as a surgical dressing. It is used almost exclusively in the form of iodoformized gauze, by means of which it is brought and held in close contact with the surfaces upon which its antiseptic action is desired.

OTHER IODINE COMPOUNDS AS SUBSTITUTES FOR IODOFORM.

The antiseptic properties of a number other of the compounds of iodine have been demonstrated by clinical use in the effort to find an agent that should have the advantages of iodoform without its disa-

[1] Cadaverin, Iodoform und Eiterung. *Deutsche Medicinische Wochenschrift*, 1888, 32, 653.

greeable odor and its toxic qualities. Of these the following are worthy of more especial mention:

Aristol (Di-Thymol Iodide). A compound containing 45.8 per cent. of iodine, formed by the reaction between thymol and iodine and iodide of potassium in the presence of sodium hydrate. A pale, chocolate colored amorphous powder, insoluble in water, slightly soluble in alcohol, readily in ether.

Airol (Oxyiodide of Bismuth Subgallate). A compound formed from basic bismuth gallate by substituting an atom of iodine for one hydroxyl group. A light greenish gray, fine, inodorous and tasteless powder.

Iodol (Tetra-Iodo-Pyrrol). A compound containing 89 per cent. of iodine, formed by reaction between iodine and pyrrol in the presence of alcohol. A yellow, inodorous, tasteless powder, insoluble in water, but freely soluble in alcohol.

Nosophen (Tetra-Iodo-Phenol-Phtalein). A compound containing 60 per cent. of iodine. It is obtained by the action of iodine on a solution of phenol-phtalein. It forms a pale grayish inodorous and tasteless powder, which is fine and light, insoluble in water and alcohol, and can be exposed to heat up to 255° C. without injury.

Each of the substances named have valuable properties to restrain the growth of organisms, lessen serous exudation and stimulate cell activity in the surfaces with which they are brought into contact; they have not been found, however, to be as efficient as iodoform in the special classes and conditions of wounds for which, as has been stated, that agent is most frequently indicated, in the treatment of which iodoform still remains unequalled.

SALTS OF BISMUTH.

Bismuth Subnitrate and *Bismuth Subgallate* possess antiseptic properties very similar to the iodine compounds mentioned. They are of value more especially when used as a powder to be dusted over the skin surrounding a wound to restrain the activity of epidermal organisms, and as a powder applied to granulating surfaces to promote its cicatrization. In the experience of the writer the last property is displayed by the ***subiodide of bismuth*** to a more marked degree than by any other agent.

SALTS OF ZINC.

Zinc Oxide, Zinc Chloride, Zinc Mercuric-cyanide, and Zinc Sulphocarbolate, also compounds with boracic, stearic, salicylic, and gallic acids, all possess antiseptic properties, and by abundant clinical tests have been demonstrated to have great practical value. All, with the exception of the chloride and the sulphocarbolate, are comparatively insoluble in water, and are used either as dusting powders or entangled in the meshes of gauze, as a substitute for iodoform. They stand, as regards practical value, about on a par with the bismuth compounds.

Zinc Oxide is especially worthy of mention and commendation as a dusting powder in the treatment of burns, excoriations and abrasions, and for use upon the skin about a wound and along a suture line. It restrains the activity of the epidermal organisms. It is itself perfectly unirritating, and with serous secretions forms a bland and soft magma. It is odorless and nontoxic. A mixture of equal parts of zinc oxide and of water, with the addition of 10 per cent. of zinc chloride, forms a paste which, when applied to skin wounds, rapidly dries into a firm protective crust or artificial scab. This is the zinc-paste dressing of Socin. It is of especial use in wounds about the lips and face, or other parts of the body where the use of ordinary dressings is inconvenient.

Zinc Chloride is very soluble in water, and in its stronger solutions is powerfully caustic. A strength of 1-50 is required to destroy pyogenic organisms, and in this strength the living tissues are affected by it, a zinc-albuminate being formed which appears as a white translucent film covering the surfaces to which it has been applied. Its use is restricted to the disinfection of wounds that are already frankly septic. Solutions of from 5 to 8 per cent. strength should be used. The film of zinc albuminate which results is markedly resistant to new bacterial invasion, and further restrains exudation and protects mechanically the underlying tissue. This combination of qualities makes it an antiseptic agent of the greatest value in dealing with open infected wounds.

Zinc Sulphocarbolate, a soluble crystalline salt formed by the reaction between zinc sulphate and barium sulphocarbolate, possesses the bactericidal properties of zinc chloride without its caustic effects. As regards its antiseptic properties and uses, it resembles rather carbolic acid, but must be used in stronger solutions.

MISCELLANEOUS ANTISEPTIC AGENTS.

The number of agents which have been demonstrated to possess antiseptic properties is very great. Their effects are due to varying degrees and kinds of influences exerted upon bacterial growth and tissue cell activity. Among these should be mentioned Aluminum Acetate, Acetanilid, Hydrogen Peroxide, Mercuric Iodate, Naphthalin, Beta-Naphthol, Pyoktanin, Formic Aldehyde and Heat. Of these agents special consideration need be given only to the two last named.

FORMIC ALDEHYDE—FORMALIN.

Formalin is the commercial name of a forty per cent. aqueous solution of formic aldehyde gas, in which strength it is supplied by chemists as a standard preparation. The gas is derived from methylic alcohol, by passing vapors of the alcohol mixed with air over glowing coke or platinum spirals. The solution is colorless, but has a pungent odor. For surgical use the standard solution is diluted down to a strength of from one to two per cent. Pyogenic organisms are destroyed within thirty minutes when immersed in a one per cent. solution, and their growth is inhibited by a solution as weak as 1 to 10,000. Even weak solutions are irritating to raw wound surfaces, and the pain following its application is so severe and continuous that it is not suitable for wound disinfection, and that its use is greatly restricted for skin disinfection, for which it would otherwise be especially suitable. It possesses a marked property as a deodorant, and in the experience of the writer has been especially serviceable as an application to such offensive sloughing conditions as are presented by inoperable necrotic malignant growths. It is efficient for the sterilization of catgut, but unfortunately with so much weakening of the tensile strength of the catgut treated with it that its use for this purpose is impracticable.

Formaldehyde Gas exerts a powerful bactericidal action upon the surface of all articles with which it may be brought into contact, without any injury to them. On account of this property, it promises to be especially valuable in the field of public sanitation for the disinfection of apartments and of articles that would be injured by heat. For surgical purposes it is more particularly available for the disinfection of soft rubber and gum elastic urethral instruments, these instruments being

suspended in suitable jars or metal boxes in the bottom of which tablets of solid polymerized formaldehyde are placed, from which fumes of the gas are gradually liberated in sufficient quantity. It may be used for sterilizing catgut and dressing materials, especially such as are charged with materials liable to be injured by heat, as iodoform.

HEAT.

The temperature of boiling water, 212° F., is sufficient to quickly destroy all known pathogenic bacteria. Most spores are also destroyed by this degree of moist heat, but so marked a power of resistance inheres in some spores that they are not destroyed by even so long an exposure as two hours. For ensuring the absolute destruction of all spore life the method of *fractional sterilization* is available. After a first boiling for twenty minutes, the fluid is kept for twenty-four hours at ordinary room temperature to permit during this time the development of any undestroyed spores into vegetative bacteria; it is then boiled again. A third repetition of this process is sufficient to ensure complete destruction of bacterial life in any form. A considerably lower temperature, down to 140° F., when applied in this manner, is sufficient to secure full sterilization.

None of the ordinary pus-forming bacteria are spore bearers, so that their destruction, in such dressings and instruments and materials to be used in wound-treatment as will not be injured by moderate heat, is simple and rapid. The thermal death point of the various forms is given by Sternberg, as follows: Staphylococcus pyogenes aureus, 136.4° F.; citreus, 143.6°; albus, 143.6°; streptococcus pyogenes, 129.2°; bacillus pyocyaneus, 132.8°; bacillus coli communis, 140°; the length of exposure being ten minutes. When micro-organisms in a desiccated state are exposed to dry heat a much higher temperature is required for their destruction than when they are moist or when they are exposed to the action of hot water or moist steam. For destroying the ordinary pyogenic organisms exposure to at least 212° of dry heat for one hour is required, but to ensure the destruction of spores an exposure of three hours or more to a temperature of 284° F. is necessary.

The possibility of using heat conveniently in the shape of boiling water or of steam for the absolute and certain destruction of bacteria has

caused these agents to very largely supersede chemicals for the disinfection of instruments, dressings and many of the accessories used in the treatment of wounds. Many mechanical devices have been invented for the purpose of facilitating the application of heat to practical surgical use. Proper description of such of these as are of importance will be given in their appropriate place.

PART I.

IN GENERAL.

SECTION II.

THE PRACTICE OF WOUND TREATMENT.

CHAPTER VI.

THE PREVENTION OF INFECTION.

Equipment for Preliminary Sterilization—Availability and Value of Heat as a Means of Sterilization—The *Operating Room*—Location—Construction—Provision for Spectators—Accessory Rooms—Operations in Private Houses—*Tables and Utensils*—Water Supply and Fixtures—Sterilized Water—Irrigating Solutions—*Instruments and Appliances*—Apparatus for Boiling—Chemic Sterilization—*Materials for Sutures and Ligatures*—Sterilization of Wire and Silk—Silkworm-gut—*Catgut*—Lister's Methods—Corrosive Sublimate Method—Palladium Chloride Method—Boiling in Cumol—Boiling in Alcohol—Exposure to Formaldehyde Gas—*Sponges*—Marine—Gauze—*Dressings*—Sterilization of Gauze by Steam—Boro-Salicylated Moist Dressings—Iodoform Gauze—Oxide of Zinc Gauze—Cotton Wool—Protecting Sheets and Towels—*Precautions to Be Observed by Surgeons, Assistants and Nurses*—Operating Suits—Care of the Hair and Beard—Sterilization of the Hands and Forearms—Scrubbing—The Alcohol Rub—The Corrosive Sublimate Bath—The Potassium Permanganate and Oxalic Acid Treatment—Use of Gloves—Sterilization of the Skin of the Patient—Use of Protective Sheets and Towels.

It is impossible to exaggerate the importance of preventing the access of active micro-organisms to wounds, since by their exclusion the chief causes of disturbances in the wound healing are escaped, and the speedy progress of the healing of the injured tissues is practically assured. In the deliberate wounds made by a surgeon in the course of the operative treatment of surgical conditions, it is possible to secure a much greater certainty of the absence of such infection than can attach to accidental wounds. For the latter, methods of *wound-disinfection, wound-drainage* and *tissue-stimulation* have their special place; for the former, methods of *preliminary sterilization* are of supreme importance. For those wounds in which infection is active, the technique is properly called *antiseptic;* for those in which infection is prevented, the technique is *aseptic.* To secure asepsis in his work constantly engages the earnest effort of the surgeon; it requires from him unremitting attention to many most minute details in which are involved the practical application

of the principles which have been set forth in preceding chapters. In hospitals in which large numbers of operative wounds are made, and to which large numbers of accidental wounds are brought for treatment, a somewhat elaborate equipment is desirable to meet readily and promptly the demands both of asepsis and of antisepsis. While such an equipment involves many details, those that are essential are not necessarily complicated nor expensive. The fact that iron, glass, marble and encaustic tiles are less absorbent and present surfaces that can be more certainly and easily rendered sterile has recommended them for use in the construction of operating rooms, and wherever practicable in the furniture and accessory apparatus of such rooms, but these substances can to a large extent be replaced by less expensive materials, and even in an ordinary dwelling-house it is quite possible to secure the conditions necessary for aseptic work. Any surgeon who for his work can command an entourage of non-absorbent and smooth surfaces should certainly seek it, for thereby his work in securing asepsis will be made less difficult and the probabilities of failure lessened. On the other hand, the surgeon whose work must be done in less favorable surroundings need not despair of securing equally good results by intelligent, diligent and unremitting attention to the essential principles that govern the presence, the diffusion, the activities and the life-history of micro-organisms. Simplicity of arrangement and of method should be always studied in providing for the equipment required in wound-treatment, so that supervision shall always be easy, and absolute certainty in the adequacy of the bactericidal means employed may be readily demonstrable or faults may not escape detection. The introduction of processes of sterilization by heat has simplified greatly the problem of rendering aseptic the materials that have to be brought into contact with wounds or that are required for their support and protection during the process of healing. Thermic sterilization is much more readily and certainly accomplished than is chemic sterilization. The means for applying heat, especially moist heat, have become therefore of great importance in the provisions necessary for the aseptic treatment of wounds. In the emergencies of ordinary practice the facilities found in every kitchen may usually be made to answer the needs of thermic sterilization, but for the systematic and extensive sterilizations required in the work of an hospital

service special and more convenient appliances are needed and have been devised.

The various problems involved in the practical application of asepsis to wound-treatment may be systematically discussed under the heads of: *Room, Spectators, Tables and Utensils, Instruments and Appliances, Dressings, Surgeons and Nurses, Preparation of the Patient.*

Room.—The *location* of the room in which wounds are to be exposed is not a matter of indifference. The observations of Miquel (page 41), that floating micro-organisms were more than ten times as numerous in the air in a densely populated quarter of a city than in a part on the outskirts of the same city, show that from this source, infection by floating material in the air, liabilities to infection are much greater in wounds made in such a city location than in the country or in a sparsely settled suburb, and give added weight to the recommendation to select for hospital purposes parks and suburban sites. The fact that in the lower strata of air in any location floating micro-organisms are more numerous than at higher levels indicate that, when a choice of levels can be made, the place of an operating room should be on an upper rather than a lower floor, the higher up the better. That the special hazards attaching to operating rooms at the ground level or but slightly elevated above the ground can be rendered of little importance by greater attention to other precautions is shown by the experience of many large hospitals, such as that in the Friedrichshain Park at Berlin, or in the Eppendorf suburb of Hamburg, or at the City Hospital of Boston, or the Johns Hopkins Hospital of Baltimore, or the Roosevelt Hospital of New York. The very general use of lifts or elevators in public buildings serves to practically make all floors on the same level as far as convenience of access is concerned, and makes it possible in many instances to choose an upper floor for operating room purposes without embarrassment to the service, or difficulty in the transportation of patients. It is desirable that there should be such isolation of the room that there shall be no possibility of access to it of air currents from the wards or from waiting rooms, and that, on the other hand, the odors and sounds incident to surgical work shall not reach other parts of the hospital. With this precaution observed, such a room should be as near as possible to the wards to which the patients are afterward to be transferred, for it is not a mat-

ter of indifference to patients, who are in a state of anxious expectation, to be carried a long distance to the place of operation, or when in a state of depression after serious operations to be carried long distances to their beds. From this point of view, also, a location upon an upper floor has many advantages. The needed isolation of an operating room does not necessarily require that a separate building be provided for it, although when an hospital is composed of a number of separate pavilions the convenience of service would usually best be secured by a centrally located separate building. Such a building should always be connected by suitable covered corridors with the pavilions containing the wards in order that exposure of patients to weather conditions during transit to and from the operating room may be avoided.

In the *construction* of an operating room it is important to secure surfaces to which dust shall not readily cling and which can be freely flushed with water. The utmost plainness and simplicity of the room itself is required; projecting mouldings, as in window casings and door frames, must not be used. All angles, as at the corners and at the junction of the walls with the floor or ceiling, should be rounded; no shelving or permanent fixtures should project from the walls, and all fixed pipes, stands or utensils of any kind that are placed in the room should be at sufficient distance from the walls to permit inspection of every part and ready access for cleaning.

The floor is best covered with smooth, non-absorbent tiles, or with the small, irregular pieces of marble set in cement and polished to an even, smooth surface, known as "terrazzo." The surface of the floor should gently slope from every side to a central point, where an opening should be provided for the escape of fluids. The drain leading from this opening should be properly ventilated and trapped; that it should empty into an open intercepting basin is sufficient.

The walls should be wainscoted to a height of six feet with white glazed tiles; upon the remainder of the wall and ceiling surface may be placed ordinary hard-finished plaster, to which a coat of paint is added, to be renewed from time to time. The height of the ceiling should not be so great that it cannot readily be reached with brush and hose-jet for purposes of cleaning. It will have to be broken by an ample skylight opening. Abundant side light is also required. Wooden doors,

with smooth surfaces, polished or painted, satisfy the requirements of an aseptic technique.

For the heating and ventilating of an operating room the methods generally accepted in hospital construction suffice, but special caution is to be taken that strong currents of air be not directed toward the parts of the room occupied by the operating tables.

PROVISION FOR SPECTATORS is a requisite, if the important teaching element of an hospital is not to be entirely ignored; it assumes great importance if public clinical demonstrations are to be made of surgical operative work. The presence of numbers of persons moving about in a room tends to disturb and disseminate through the air of the room particles of dust which may have settled upon the floor and seats in such a room, and hence it becomes important that immediately previous to the admission of spectators the amount of such dust shall be diminished as much as possible by flushing the floor and wiping the seats, and that the whole construction and arrangement should be such as to permit the free flushing of every surface and corner. Micro-organisms are not shed into the air to any large extent from the skin or the clothes of persons sitting quietly in a room; but, on the other hand, in the process of respiration, floating organisms are filtered out of the air and fixed upon the moist surfaces of the nares and mouth. The essential point in providing for spectators is that proper barriers be placed so that they shall not come in contact with operators, instruments or dressings, and that they shall be elevated so as to give them a view of the field of work. The number of spectators need therefore be limited only by the capacity of the room, or by the ability to see what is being done. The construction of large theatres with seating capacity for from one to four hundred spectators is, however, to be deprecated. The service required for the proper cleansing and care of such a room is difficult to secure or maintain, and it is not possible for the great mass of the spectators to see clearly anything of the operation itself. The size of the classes admitted to clinical operating theatres might profitably be limited to that number which can have a close view of the work that is being done. It is not likely that accommodations for more than fifty spectators at any one time would be required if such a test as this was made to govern the matter.

Accessory Rooms, conveniently grouped about the operating room itself, are necessary for the proper carrying on of its work. For the patient there should be provided a room in which the anæsthetic may be quietly given, apart from the sights and sounds of the operating arena. A room for the temporary detention of patients after opera-

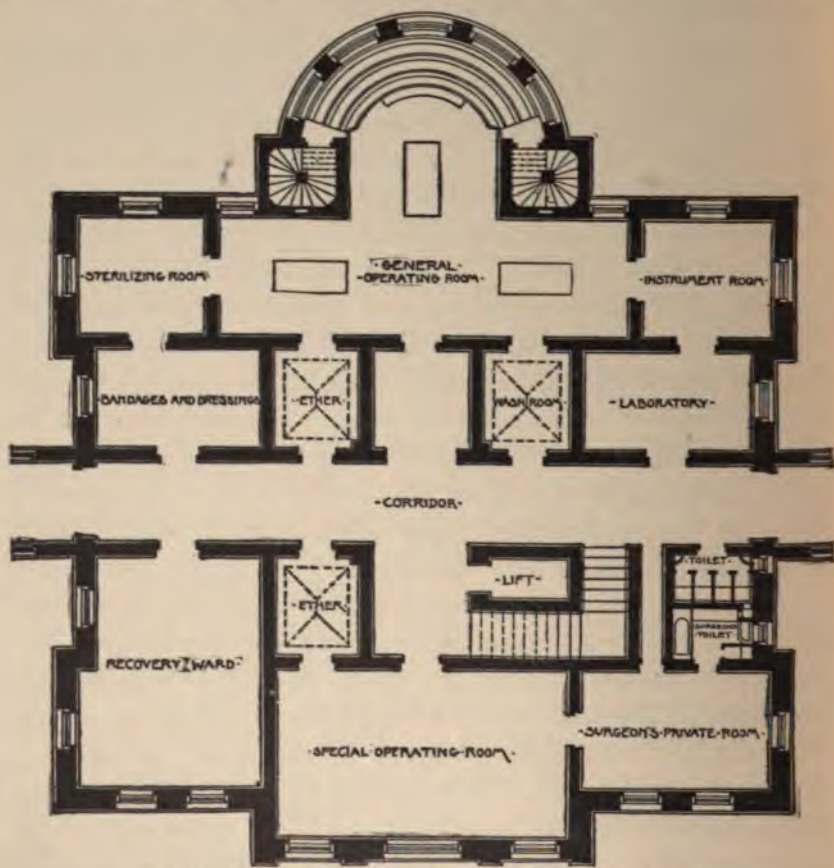

Fig. 12.—Floor plan for an operating room and accessory rooms.

tion is important, where the necessary cares to secure recovery from shock may be given, and the moanings, incoherent cries and vomitings attending recovery from the anæsthetic may have their vent before the patient is taken back to the presence of others in the wards. There should be a room for the storage and manipulation of materials required for surgical dressings, previous to sterilization; connected with

this should be facilities for the nurses for hand sterilization; a separate room fitted up with apparatus for sterilization of dressings and clothing, and for storage of same until called for, is needed, and yet another room for the storage of instruments, with apparatus for their sterilization, is important. In this may be included the arrangements required for the preparation and storage of suture and ligature materials.

Adjacent to the operating arena should be also a room fitted up as a wardrobe and lavatory for the surgeon and assistants, in which the necessary changes of clothing and the washings and purifications required for hands and forearms can be made. A laboratory room with facilities for bacteriological, microscopic and photographic work is likewise required. For the surgeon-in-chief a separate room should be provided, with bathroom and lavatory facilities, with writing desk and wardrobe. Case records should be kept in this room. In an hospital in which there is an active surgical service a second operating room should be provided. Figure 12 is a sketch in which is given a suggestion for the grouping of such a series of rooms as has been mentioned. They are intended to be placed on the first floor of a separate building, the ground floor of which is devoted to a surgical outpatient service, and to an accident reception ward. The corridors on either side connect it with pavilions of wards.

Abundant experience has shown that adequate asepsis can be secured when miscellaneous conditions, whether of a septic character or not, are cared for in the same room; extensive operations within the peritoneal cavity, the management of compound fractures of the large bones, attacks upon intracranial conditions, or the opening of large joint cavities, can be conducted safely in the same room in which operations are done for the relief of osteomyelitis, of empyema, or for affections involving the mouth or rectum. That freedom from septic infection should be secured under such conditions requires, however, great watchfulness and the most exact compliance with the technique of disinfection.

When an operation is to be done in a *private house,* it is possible usually to apply to the selection and preparation of the room much of the essentials that have been described as required in an hospital operating room. An upper room should be chosen; on the day previous to the operation it should be dismantled of its curtains, pictures, carpets

and furniture, and its walls swept down and all accumulated dust wiped up from floors and mouldings. It should be left undisturbed over night

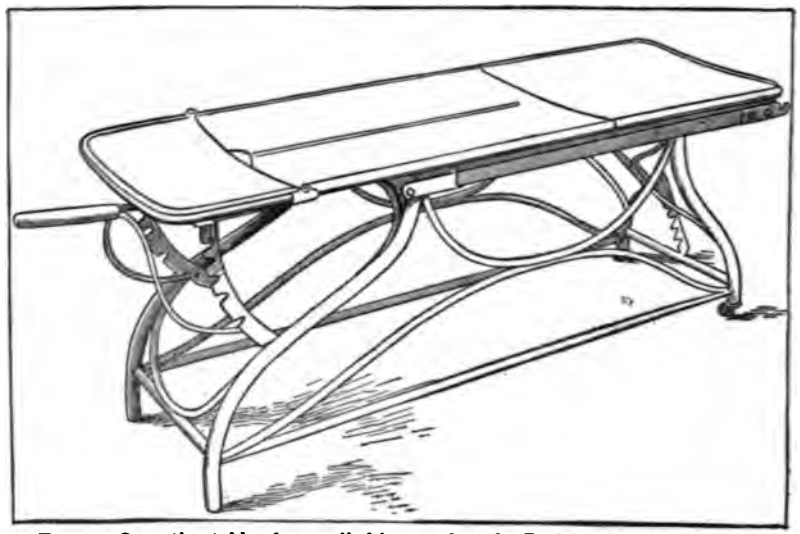

FIG. 13.—Operating table of enamelled iron and steel. Position for general use.

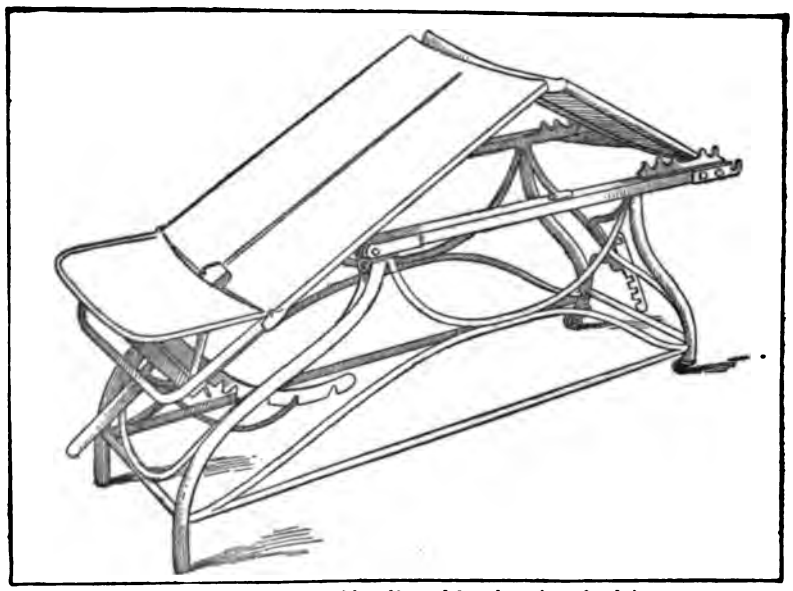

FIG. 14.—Operating table adjusted for elevation of pelvis.

for dust to settle, and in the morning the floor should be copiously sprinkled and kept damp until the operation is ended.

TABLES AND UTENSILS should be characterized by simplicity of model and by the ease with which every part can be exposed and reached for cleansing. Iron and glass should be the materials used in their construction as far as possible. The frames of all tables, stands and stools should be made of iron, covered with white enamel paint; the tops may be of thick glass or of enamelled iron. A very large number of different models for operating tables, to be made of iron, or iron and glass, crowd the pages of the catalogues of dealers in surgical supplies. The one which is represented in figures 13 and 14 has satisfied the needs of an active general surgical service in my own hands for some years. By simple pressure on the lever, which projects at the head of the table, the change of position is made required for elevating the pelvis, shown in Figure 14, without disturbing the patient. A gallows attachment is affixed to the foot of the table for supporting the legs when the exaggerated lithotomy position is required. Portable tables of suitable size are required for the reception of instruments, sponges and other materials during operations. Basins and pans, to contain the fluids needed for frequent immersion and rinsing of the hands of operator and assistants during operations, must be provided. They may be of glass, but the enamelled ironware known as "agate ware" is quite as satisfactory and much more durable and less expensive. Instrument cases should not be placed in the operating room, but should be kept in an adjoining room. They should be constructed of iron and glass, with movable glass shelves. See Figure 15.

An abundant supply of water, with facilities for simultaneous hand washing and scrubbing of from four to six or more persons, is an important requisite. It is preferable that these lavatory arrangements be not in the operating room itself, but that they be placed in a room immediately adjoining. The idea of a wash-basin for holding water to be applied over and over to the hands in the process of washing is not to be entertained in connection with purification for surgical work, and no such basins should be provided. The necessities of hand purification are best met by a long porcelain or enamelled iron sink over which project at suitable distances the required number of faucets—"mixing taps" of the plumber—by which water of any degree of temperature can be supplied. By the running water from such a tap the lather

produced by the soap and brush vigorously applied to the hands and forearms is from time to time washed away, until the required cleansing of the skin has been accomplished. It should not be forgotten that the faucets of such an apparatus, being frequently handled by the unsterilized hands, are presumably unclean, and therefore should not be touched by the hands at the close of the cleansing process. To avoid this ingenious devices have been elaborated whereby the faucets may be opened and closed by levers moved by the feet. These are convenient and desirable, but in their absence, by the use of a napkin or towel

FIG. 15.—Instrument cabinet of iron and glass.

saturated in a sublimate solution, the surgeon can usually manipulate the faucets without danger of contamination.

For the cleansing of instruments a convenient sink with a large marble "drip-board" should be provided. This should be placed, not in the operating room itself, but in the room assigned to the care and storage of instruments.

Sterilized water can be secured by boiling for half an hour, and an abundant supply is desirable to have always at hand. A suitable boiler and a gas stove supply the necessary means. For the large quantities

needed in an hospital clinic, in which steam is always available, it is convenient to utilize a reservoir lined with a steam coil. The reservoir being filled with water, by permitting the steam to flow through the coil the water is quickly brought to a boiling point. A reservoir in which the sterilized water can be retained and cooled without exposure to contamination is a desirable adjunct. In most places the filtration

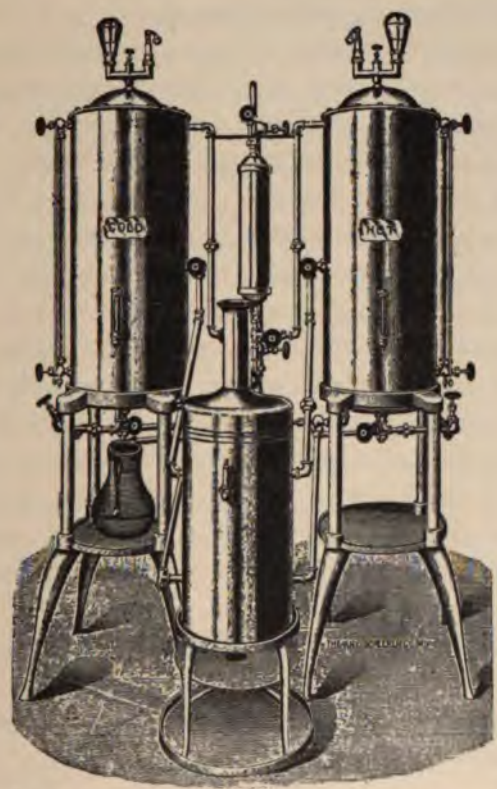

Fig. 16.—Apparatus for the production and storage of sterilized water.

of the water before it is admitted to the boiling vat is important to prevent the accumulation in the reservoirs of troublesome sediment. In Figure 16 is shown a combination of filter, boiler and storage tanks such as is used in a number of the larger hospital clinics of this country. The water from the general water supply of the institution is first admitted to the narrow cylinder between the two large ones in which it is

filtered, thence it passes to the boiler below, where it is heated by gas or steam, as the case may be, thence it passes to the storage reservoirs on either side, from which it is drawn as needed. The air entering the reservoirs as the water is withdrawn passes through a filter of cotton to prevent accidental contamination of the water from any floating matter in the air.

Such an apparatus should be placed in the room devoted to sterilizing work, and not in the operating room proper.

A certain number of large glass jars to contain irrigating solutions should be placed upon a shelf at a suitable height to secure sufficient force for flushing purposes. Rubber tubing, stop-cocks and glass irrigator tips are required to complete the irrigation outfit. While irrigations are much less freely needed in aseptic technique than in dealing with infected wounds, there are frequent occasions when they are convenient. The physiological saline solution is usually indicated. Occasional need for a solution of boro-salicylic acid occurs. A solution of corrosive sublimate—1-2000—is sometimes of value. In my own operating room these three solutions are kept always ready. For these irrigators two separate sets of tubes and nozzles should be provided for use; each set, when not in use, to be kept immersed in 1-2000 sublimate solution contained in an individual glass jar. For the flushing of a peritoneal cavity or a knee joint I am unwilling, however, to trust the immaculateness of any apparatus so complicated and exposed to contamination as the ordinary irrigation apparatus, and by preference avail myself of glass "Florence flasks" of the chemist, filled with saline solution, and recently sterilized by repeated exposure to steam heat. From these flasks the fluid is poured out, as from a pitcher, into the cavity or upon the surface to be flushed.

INSTRUMENTS AND APPLIANCES.

In the choosing or devising of surgical instruments two points should always be regarded; first, simplicity of model and plainness of surface, without angles or crevices, notches or grooves, that would make mechanical cleansing difficult; second, the use whenever possible of material that will not be injured by exposure to moisture at a temperature of 212°, for whenever the material of which an instrument or appliance

is made is such that it will not be injured by moisture and a temperature of 212°, moist heat should be resorted to for its sterilization.

Many instruments, such as knives, retractors, chisels, curettes, and the like, can be made from a single piece of forged steel. Others, such as scissors, forceps and hæmostatic clamps, must necessarily be made in two parts. It is desirable that the parts of a complex instrument should be so joined as to permit of being quickly taken apart and easily rearticulated, and much ingenuity has been devoted to this end in devising the locks of such instruments. While this feature is desirable, it is less important in instruments that can be boiled than in those for the sterilization of which mechanical scrubbing and immersion in chemical solutions must alone be trusted, since the effects of the heat are both pervasive and certain, however complicated the mechanism. The accurate fitting together of the parts of such instruments as scissors and hæmostatic clamps is so quickly lost in any disarticulable model, from the natural wear of the posts and sockets incident to use, that the use of a fixed articulation with screw or rivet is needful for certain and delicate work. The surgeon need not hesitate to choose fixed articulations for such instruments, since, although the mechanical cleansing of them will be less easy and will require more time, yet no difficulty or uncertainty attends their full sterilization by boiling. In the case of such complex instruments as the trephine and the chainsaw, or of tubular instruments as catheters, trocars and aspirating needles, boiling is the only efficient as well as the most simple means of sterilization.

The rusting of steel instruments from frequent boiling can be prevented by the addition to the water of a small amount (one per cent.) of sodium carbonate (ordinary washing soda). This has the added merit of raising slightly the boiling point of the water, while the alkali attacks and saponifies any trace of fatty or oily matter that might be present, possibly enveloping and protecting an organism or spore. Practically it suffices to add to each gallon of water used a handful of the soda.

No elaborate apparatus is required for the application of this method of sterilizing instruments. Any clean pot or kettle will do, and the heat of a stove, gas burner, or oil or alcohol lamp, as may be most convenient. The ordinary fish-kettle of the kitchen, Figure 17, is an ideal

contrivance for this work, provided its perforated tray is made into a basket by a two or three inch high band of wire-netting carried around its base. Such an apparatus can be extemporized by any tinsmith in a couple of hours, as I have found by personal experience. For the larger and more incessant needs of a hospital operating room a larger and more substantial apparatus, as is shown in Figure 18, will be desirable, but the principle of its construction is the same. A wire basket fitting inside the boiler is needed to facilitate the manipulation of the instruments. Boiling for five minutes is sufficient to ensure the sterilization of the materials in the boiler. (See page 90.) At the end of this time they are lifted out of the boiling solution and laid upon sterilized towels upon a clean table-top, ready for use as needed. It is well to protect them meanwhile from access of any floating matter in the air by keeping them covered with a sterilized sheet or towel. The accidental contamination of an instrument during an operation may be remedied by plunging the instrument at once into the boiling soda solution while the operation progresses. At the end of five minutes such an instrument may again be used. Likewise the renewed sterilization of instruments, for use in successive opera-

FIG. 17.—Fish-kettle for sterilization of surgical instruments by boiling.

FIG. 18.—Hospital apparatus for the sterilization of instruments by boiling.

can be secured with facility in the same way. The use of glass
s, porcelain trays or special receptacles of any kind for instruments
sterilization is unnecessary, as is also their immersion in any fluid
ution. It is simply required that a sterile surface be provided upon
they may lie, and that they be protected from floating matter in
rrents, or from such accidental contamination as the brushing of a
erilized shirt-sleeve or coat-tail over them, or from handling by a
terilized hand of careless attendant or curious spectator. It will be
ıl in avoiding such accidents if the table provided for instruments
igh one, at least 50 inches, and also movable, so that it may be easily
d to follow changes in the position of the field of operation. The ad-
ın of spectators with unsterilized hands and garments to the vicinity
trument table, or of the operative field, should be strictly denied.
ertain instruments, such as the thermocautery apparatus, cysto-
and other devices for electric illumination, mirrors and syringes,
t be boiled. Many of these can, however, be immersed in a solu-
f carbolic acid, 1-40, without being injured, and this method should
ed for such. In other instances it will be sufficient to envelop the
of the instrument to be grasped in the surgeon's hand with a sterile
instead of sterilizing the instrument or appliance itself.

rticles made of soft rubber are injured by prolonged or repeated
g, and also by prolonged immersion in solutions of carbolic acid
corrosive sublimate. Nevertheless it will often be necessary to
use of these means of sterilization for such appliances as the
bandage, drainage tubes and catheters. The fumes of formalde-
may be used for the sterilization of articles of this class, by sus-
ng the articles to be sterilized in a suitable jar or other closed, dry
acle, in the bottom of which are placed tablets of the solid polymer
e gas, paraform, which by gradual volatilization generate and
ain a supply of the gas in sufficient amount. In Figure 23 is
a convenient contrivance for this purpose. Catheters or rubber
g are suspended in a glass cylinder from a perforated plate at C;
pper part of the cylinder is closed by a ground glass stopper, A;
wer part is ground so as to fit into the top of a small chamber, B,
ich the paraform tablets are placed, together with chloride of
m crystals for the perfect dehydration of the jar. Less elaborate

and expensive, and equally as efficient, arrangements can readily be extemporized out of an ordinary fruit-jar, an ointment-pot or a salt-cellar, and a bit of wire gauze.

Materials for Sutures and Ligatures.—These include threads of silver wire, of silk, of silkworm-gut, and of catgut. The *wire* thread is sterilizable by boiling the same as any cutting metallic instrument. The *silk* thread may also be boiled or steamed. For purposes of convenience for use and of preparation, the silk thread, as obtained from the shops in skeins or on spools, may be cut into shorter lengths of about two yards each, and each of these pieces be wound on a separate glass reel or bobbin. One or two of these reels of thread may be put in a suitable wide-mouthed glass jar, like the glycerine-jelly jars of the pharmacist or the test tubes of the chemist; the mouth of the jar is then loosely stopped with a plug of ordinary cotton wool and put in a steam sterilizer for an hour, and again for a half hour each on the two following days, during which time they are exposed to the effects of steam under pressure reaching a temperature of from 220° to 240°. At the close of the final steaming the cotton is pushed tightly in and the jars are stored away in larger glass containers until needed for use. Only one reel of silk is to be taken out at a time during the progress of an operation. Any thread which may be left unused after having been taken out should be thrown away, for repeated heating weakens the thread to such a degree that it cannot stand much tension. For the emergencies of operative work, when thread thus previously prepared is not at hand, it will suffice to throw a spool or reel of thread into the boiler with the rest of the instruments and treat it as any instrument.

Silkworm Gut may be sterilized by steaming, or by prolonged immersion in carbolic acid solution, 1-30. Since the increased pliability of the gut resulting from immersion for some time in water is very desirable, and the action of the carbolic acid is not injurious to it, all that is needful for the preparation of this material is that it be simply immersed in a watery solution of the acid and kept in it indefinitely until used.

Catgut presents special difficulties in its sterilization without lessening too much its tensile strength or its pliability in the process. Its source as a bit of animal membrane twisted into a thread, and the

process of its manufacture, make so certain and intense its infection, as met with in commerce, that especial thoroughness in the means instituted for sterilizing it is demanded. The use to which it is put as a buried ligature or suture makes it of the highest importance that it should be absolutely sterile, but it must also be strong, pliant and absorbable. No surgeon can rely upon the disinfection of a given strand of catgut unless it has been prepared by himself or under his own personal direction, wherefore any method of preparation which can commend itself for general use must be one which is easy of execution and requiring simple apparatus. The method advised by Mr. Lister in 1881 was to immerse the gut for forty-eight hours in a 1-20 watery solution of carbolic acid, containing one part to 4,000 of chromic acid; then remove and dry, and lastly immerse in a mixture of carbolic acid and olive oil, 1 to 5, in which it was to be kept indefinitely until used. Later he recommended as a better method the soaking of the gut for twelve hours in a one per cent. solution of chromic acid, and then for twelve hours more in sulphurous acid (B.P.); then to be dried, in which state it was to be kept until needed for use, when it was to be soaked in a carbolic solution for fifteen minutes before using.

These methods have, however, long been entirely abandoned by surgeons in general as inefficient and unreliable, and are merely mentioned here for the historic interest which attaches to them. Many different processes for sterilizing catgut have been proposed during the past twenty years; a few only of these need be mentioned.

The Corrosive Sublimate Method.—The raw catgut is soaked in ether for twenty-four hours or more to remove its fatty elements, then immersed in fresh ether containing corrosive sublimate in the proportion of 1:4000; after standing in this new ether for a week the gut is transferred to bottles containing sublimate and absolute alcohol, 1-4000, in which it remains till needed for use (Morris).

Palladium Chloride Method.—W. W. Keen praises the following method as producing an absolutely reliable sterilization of catgut with such simplicity of means and little expenditure of time as to commend it for use by general practitioners. The resultant thread is strong and flexible and quickly absorbed, and by extensive clinical and bacteriological tests has always proven to be sterile.

The gut, as received from the manufacturer, is first steeped in absolute ether entirely purified from sulphuric acid, to remove the fat—light gut remaining twenty-four hours in the ether and the heavier gut forty-eight hours. When it has been steeped a sufficient length of time in the ether the gut is transferred directly into a corrosive sublimate solution, consisting of mercuric chloride 40 grains (2.6 gm.), tartaric acid 200 grains (12.96 gm.), and alcohol 12 ounces (354.88 c.c.). The lightest weight gut should not remain in the corrosive mixture longer than from five to ten minutes, the next size from ten to fifteen minutes, and the largest sizes from twenty to twenty-five minutes. While the gut is being steeped and before it is transferred from the ether to the corrosive mixture, jars for keeping it ready for use are prepared by thoroughly scalding, filling them with an aqueous corrosive-sublimate solution 1:1000, allowing them to stand thus filled until the following day. This solution is then emptied and the jars nearly filled with alcohol (95 per cent. strength) and containing palladium bichloride in the proportion of 1-16 of a grain (0.0040 gm.)—*i. e.*, two drops of a palladium bichloride solution containing 15 grains (0.972 gm.) of the salt to the ounce—to a pint of alcohol. By experiment it has been shown that more of the true bichloride of palladium will not stay in solution in alcohol, and when a precipitate occurs through excess of the palladium the whole goes to the bottom and is not again soluble in alcohol. The gut, being lifted with an aseptic tenaculum from the bichloride mixture, is dropped into the prepared jars of palladium-alcohol and is ready for use. Catgut thus prepared is strong, pliable, and smooth, and keeps indefinitely as far as yet known. When an operation is about to be performed the outside of the jar is rinsed with hot bichloride solution 1:1000, the glass stopper removed, and the mouth of the jar well wiped with the solution. The quantity of gut judged necessary for the operation is lifted from the jar by means of a sterilized tenaculum, and dropped into a dish previously sterilized and containing sufficient alcohol to cover the gut. If more gut is removed from the jar than is necessary for the operation the quantity left is immersed in the mercuric chloride solution for five minutes and transferred to the stock jar. This precaution gives absolute safety against infection.

Boiling in Cumol.—It having been demonstrated that if catgut was

first thoroughly dehydrated by exposure to dry heat of 160° F., it could afterward be exposed to a temperature of twice that degree without impairing its integrity, Krönig suggested that catgut, after having been subjected to the preliminary drying process, should be boiled in cumol, a hydrocarbon compound whose boiling point ranges from 334° to 352° F., a degree certain to quickly secure the absolute sterilization of any material subjected to it. The method may be carried out as follows: The catgut is cut up into the desired lengths and wound into small figure-eight-like skeins, which are each secured by a ligature about the middle of the skein. It is then placed in a hot-air oven, or in a sand-bath improvised by imbedding a beaker glass, of a half liter or more capacity, three-fourths of its height in a tin or agateware vessel large enough to give a space of at least three-fourths of an inch, filled with sand, around and beneath the glass. Here the temperature is gradually brought to 160° F. by a Bunsen burner, and held at this point for one hour.

During this drying, or the later boiling, the catgut must not come in contact with the bottom or sides of the vessel, but must be suspended on slender wire supports or be placed on cotton loosely packed in the bottom. If the temperature is raised to 212° before the absolute dehydration of the catgut it is rendered brittle and useless.

When the drying process is completed the cumol is poured into the beaker glass, and the temperature raised by the use of an additional Bunsen burner to 330°, a little short of the boiling point of the cumol. It should be held at this point for one hour. The cumol is then poured off for subsequent use. The catgut is allowed to remain in the empty beaker in the sand-bath until the excess of cumol is driven off, and it appears entirely free from any oily matter, a period of from one to two hours being required for this.

It is then transferred with sterile forceps to sterile test tubes (see Figure 19), in which it is preserved from contamination until ready for use. Kelly, from whom this description is taken, gives the caution that since cumol is very inflammable, great care should be observed in the various manipulations to prevent drops of the cumol from falling into the flame or on the heated piece of metal on which the sand-bath rests, as it will take fire, flare up and ignite the fluid in the beaker glass.

Figure 20 shows an apparatus devised by Dr. Clark, of the Johns

Hopkins Hospital, for the safe and ready carrying out of the cumol process.

Boiling in Alcohol.—The temperature at which 97 per cent. alcohol boils is 183°, which is considerably above the thermal death-point of

FIG. 19.—Method of storing catgut after sterilization by boiling in cumol.

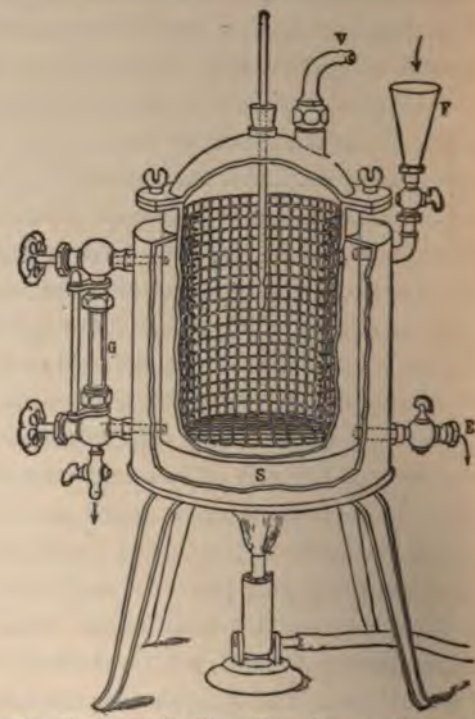

FIG. 20.—Cumol Sterilizer: E, tap for removing cumol from the cylinder; F, funnel through which cumol is poured into cylinder; G, glass gauge; S, space for sand; V, vent. The apparatus consists of a cylindrical vessel of copper, 6 inches in d ameter and 8 inches high, fixed within a similar larger cylinder so as to leave a space of one inch on all sides and at the bottom between the two, which space is filled with dry sand. The upper end is closed by a removable drum-head of cast bronze. A glass gauge shows the quantity of cumol in the cylinder and a thermometer registers the temperature of the fluid.

ordinary pyogenic organisms; pyogenic streptococci and the bacilli of anthrax, in liquids, dying at 128° within ten minutes. The spores of anthrax require, however, a temperature of 212° of moist heat and 284° of dry heat for several hours to insure death. By the process of frac-

tional sterilization the destruction of all organisms in catgut can be ensured even at the temperature of boiling alcohol. The quality of catgut, as regards its strength, pliability and absorbability, is not injured by the boiling. The method of the alcohol process, as devised by Fowler, and carried on at the Methodist Episcopal Hospital in Brooklyn since 1890, is as follows: Each strand of catgut, as it comes from the manufacturer, is wound on a glass spool and put in a small glass jar filled with

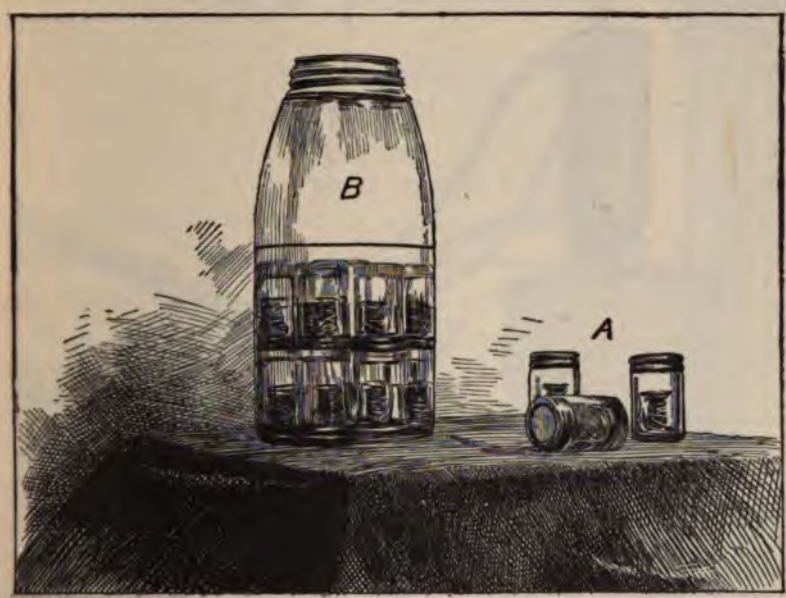

FIG. 21.—Sterilization of catgut by boiling in alcohol: A, small glass jars filled with alcohol, each containing a glass spool with one strand of catgut; B, large glass fruit-jar partly filled with alcohol, in which are immersed one dozen of the small catgut jars; the whole ready to be placed in a water bath for the boiling process.

absolute alcohol, closed by a metal cap loosely screwed on (the ordinary glycerine-jelly jar of the pharmacist)—see Figure 21, A. A number of these jars are placed, inverted, in a larger jar (an ordinary glass fruit-jar) and covered with absolute alcohol (Figure 21, B). This jar is kept in a water bath at from 200° to 212° F. for an hour; it is then allowed to stand for twenty-four hours, when it is again boiled for one hour. The small individual jars are then taken out, their caps screwed down tightly, and the jars stored away until needed for use. During

shops, require further preparation to fit them for use, for even the finer qualities of Turkey sponge still contain much sand, bits of coral and small shells, and some organic impurities. To remove the sand and other mineral matter the dry sponges should be thoroughly beaten and then subjected to prolonged and repeated washings in tepid water until the water comes off clear and free from sand. After they have dried, it will be found that a new beating will still dislodge some sand. As soon as the sponges are sufficiently freed from sand, they should be placed in a solution of permanganate of potassium, 1 to 500, for twenty-four hours. Then they are again washed in clear water, and placed in a one per cent. solution of hyposulphite of sodium, to which is added one-fifth the amount of an eight per cent. solution of hydrochloric acid (fort.). The sponges should remain in this solution only for a few minutes, until (in about one-quarter of an hour) they have become white, being constantly stirred with a wooden rod while in the solution.

It will not be well to let them remain too long in this bath, because their substance will become injured so that they will lose their elasticity and easily tear. Lastly, they are again washed until they are entirely scentless, requiring frequent changes in water during two or three days, and immersed in a five per cent. solution of carbolic acid for at least fourteen days before being used.

During the progress of an operation the sponges as fast as soiled are rinsed out in sterile water and replaced in the carbolic solution. At the close of an operation all the sponges that have been used should be thoroughly purified by repeated washing in a solution of carbonate of sodium —common washing-soda—one ounce to the quart of water, to remove any blood or other impurities, then with water again, and then immersed as before in the five per cent. carbolic acid solution. To facilitate the systematic care and reliable disinfection of sponges in an active hospital clinic, it is customary to have a distinct set of sponges for each day of the week, kept immersed in a bottle of carbolic acid solution, suitably marked with the name of the day for which its contents are reserved. By this device at least seven days' immersion in the disinfecting solution is assured before the sponge is used again.

In process of time, a sponge, after frequent using, will become so clogged with fibrine, that cannot be washed out, that it is useless. In

such cases the sponges may be allowed to macerate in ordinary water for a week or two, until the putrefaction of the fibrine has softened it so that it is easily washed out. Cleansing and immersion of the sponge in five per cent. carbolic acid solution, as before, will again fit such sponges to be used.

When sponges have been used upon surfaces manifestly impure, or about wounds to which any suspicion of infection attaches, they should be thrown away.

By the use of these measures for purifying sponges, they may be used repeatedly and for an indefinite time. Without these precautions, the repeated use of a sponge is fraught with danger, as it may be the bearer of infection from one wound to another.

Whenever a soft sponge whose purity can be relied on is not accessible, the cleansing of a wound should be attempted by some substitute for it, rather than by using a sponge of doubtful character. Pieces of cotton cloth, old, soft, and absorbent, made clean and pure at the time of using, may be made to do good service as substitutes for sponges, and are nearly always available. Dossils of absorbent cotton—cotton from which all gross impurities and fatty matter have been removed, and which is now abundantly supplied by various makers in this country—make a good substitute for sponges. They may be wrung out in any antiseptic liquid before using, and, being thrown away as fast as used, are not liable to violate cleanliness by a second use.

Absorbent gauze, sterilized by heat, in pieces of appropriate size, may be used instead of sponges in all surgical procedures, and as a matter of fact make a perfectly satisfactory substitute. For my own use, four stock sizes are prepared, which are known in the operating-room parlance, respectively, as abdominal, hand, ordinary and small sponges.

Abdominal sponges are made of eight thicknesses of gauze, eight or twelve inches square. These are sewed together around their edges, turning the raw edges in, and are again fastened by a row of stitching about one inch from the edge. They are always put up in bundles of twelve, so as to facilitate and insure accuracy of count at the close of an operation.

Hand sponges are pieces of gauze one-quarter of a yard square. They are sterilized in bundles of ten.

Ordinary sponges are pieces of gauze one-fourth the size of hand sponges.

Small sponges, for use only in sponge-holders, are one-quarter the size of ordinary sponges.

All these various-sized sponges are sterilized by boiling for at least ten minutes in saline solution immediately previous to use. No sponge after having once been used is used again at the same operation. After an operation the used sponges are collected and washed; then are boiled in a one per cent. solution of carbonate of sodium for ten minutes. After a thorough rinsing they are again boiled for ten minutes in clear water, and are put away for new use, as required.

The Dressings.—For absorbent and protective purposes the chief part of a wound dressing will be composed of suitable pieces of loosely woven, thin, gauzy cotton cloth, similar to the "cheesecloth" or "butter-cloth" of the shops; this constitutes the *"gauze"* of the surgeon. Other absorbent materials may be substituted according to the convenience of the particular case, such as pads of moss or of sawdust, masses of the cotton fibre known as engineer's waste, or of soft absorbent paper, or quantities of oakum, jute or "wood-wool"; but the superior convenience and the unequalled absorbing qualities of the gauze have caused it to be accepted almost universally as the staple dressing material. It is manufactured in large quantities, freed from oil and pectose, requiring only sterilization to fit it for use. Ordinary cheesecloth, not thus freed from fatty elements, requires to be first subjected to prolonged boiling in carbonate of sodium solution and to thorough and repeated rinsings in pure water to render it absorbent.

For convenience of use gauze may be cut into pieces each one yard square, and folded two or more times. Such a piece of gauze is known as a "handkerchief." Gauze may be cut also into long and narrow strips, to be rolled into bandages or for use as drains or for tampons.

The *sterilization of gauze* can be effected by steam, by boiling in water, or by immersion in a solution of a chemical bactericide. Steam sterilization is the most convenient. For the office uses of a surgeon, and for the needs of operations at the homes of patients, such a portable sterilizer as is shown in Figure 24 may be used. This consists of a steam chamber into which enters steam generated in a shallow copper

vessel underneath, which is kept fed by water from a capacious pan superimposed and connected with it by small apertures. In the steam chamber may be placed suitable racks for holding dressings, and over all is placed a hood, which imprisons escaping steam and condenses it so that the waste drops back from its lower edge into the primary water-pan. The apparatus causes steam to be generated under slight pressure and insures a temperature of about 215° F. Steam is very quickly generated in this apparatus by gas, alcohol or coal oil burners, or by placing it on a hot stove. By resorting to a repetition of the steaming at intervals of twenty-four hours, fractional sterilization, the absolute destruction of all bacterial life can be secured with certainty, notwithstanding the limitations of the degree of heat which attend the apparatus.

FIG. 24.—Portable apparatus for sterilizing by steam.

For the sterilization of larger quantities of gauze, and also for the treatment of such other materials as operating suits, sheets, blankets, towels, etc., a more elaborate and capacious apparatus is required, in which a higher temperature of the steam can be attained, and the subsequent drying of the sterilized materials can be secured. In Figure 25 is represented an apparatus of this nature in use in many hospitals of the United States. Large experience has shown it to be both convenient and efficient. The cut shows an open door exposing the chamber into which the articles to be sterilized are placed. The water for vaporizing is carried in the hollow jacket which encloses the sterilizing chamber, and is heated by a row of gas-jets below. A proper safety steam valve regulates the pressure of steam, which may be from ten to twenty pounds, at the will of the operator, thus insuring a temperature within the chamber of from 240° F. to 260° F. Provision is made for the exhaustion of the air in the chamber after it has been filled and the door

closed. The steam is then turned into the chamber and the articles to be disinfected exposed to it for from twenty to thirty minutes. The steam is then turned off and escape valves are opened. The chamber now becomes a drying oven, through which a current of heated filtered air is carried by suitable mechanism. After a few minutes, upon opening the door, the goods may be removed, sterile and dry.

The storage of articles sterilized by heat is to be deprecated on account of the many and unavoidable sources of contamination continually present, to be escaped only by incessant watchfulness and great trouble.

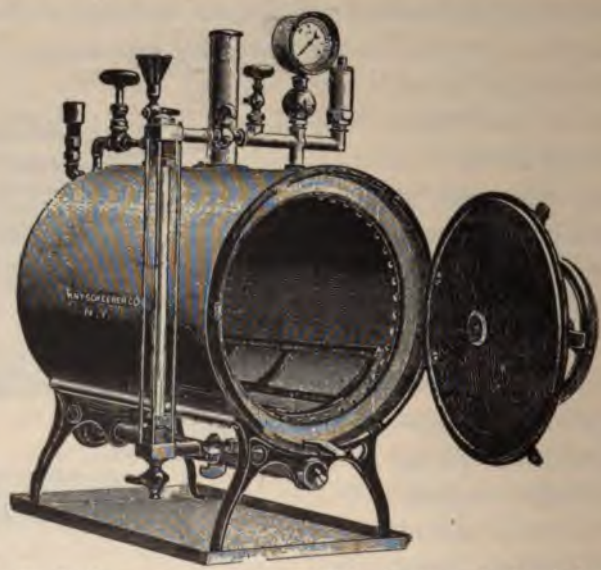

FIG. 25.—Stationary apparatus for sterilizing by steam—for hospital use.

Especially is exposure upon shelves or in drawers to be considered as almost necessarily involving speedy renewed infection. Many models of metal or glass containers have been devised for the preservation from infection and for the conveyance of sterilized dressings. None, however, are better than the ordinary glass fruit jar, which may be loosely filled with one or two gauze handkerchiefs or bandages, and, the top being left off, the whole outfit sterilized at once; then the top is adjusted and the jar put away till required. Sterilized dressings may be readily conveyed in such jars wherever needed.

Whenever possible, dressings should be conveyed directly from the

sterilizer to the operating arena at the time of an operation or the dressing of a wound, for which reason the practice of conveying patients to the specially equipped operating room for important dressings assumes importance and commands frequent adoption.

Boro-Salicylated Moist Dressings.—For the absorption of primary wound-discharges a moist dressing is superior to a dry dressing, and in view of the imperfect character of all skin sterilization, it is always more prudent to have the dressing which comes in direct contact with the skin in the vicinity of a wound moistened with a solution, which at least shall inhibit bacterial activity. Corrosive sublimate solutions at once suggest themselves on account of their potency as a bactericide, but they are too irritating to the skin to be left many hours in contact with it, and, if used freely, are liable to provoke the poisonous effects of the absorption of the drug. Carbolic acid is equally objectionable. Boracic and salicylic acids, feeble bactericides but potent as restrainers of bacterial activity, are free from the objections named as to corrosive sublimate or carbolic acid, and may be used in a solution made by dissolving one ounce of boracic acid and eighty grains of salicylic acid in a gallon of boiled water, for the preparation of a moist antiseptic absorbent dressing.

Iodoform Gauze, for tampon and drainage purposes, may be prepared by immersing strips or squares of previously sterilized gauze in a mixture composed of one ounce of iodoform, two ounces of glycerine and one quart of solution of corrosive sublimate, 1:2000. After all excess of the iodoform mixture has been wrung out, the resultant iodoformized gauze is packed in sterilized glass jars. In all the processes involved in the preparation the same precautions as to sterilization of the table and apparatus used and of the hands and person of the workman are to be observed as would be employed in a surgical operation.

Oxide of Zinc Gauze may be prepared by wringing out gauze in a mixture of one ounce of oxide of zinc and two ounces of glycerine in one pint of water. It is then put in a glass jar and sterilized in the steam chamber.

Cotton Wool, for use as an outer protective covering to the primary absorbing gauze dressings, or as padding to relieve the pressure of bandages and splints, is prepared by dividing the ordinary bolt of the shops into four or more small rolls, wrapping these loosely in suitable

pieces of slazy muslin, and sterilizing them in the steam chamber. The common cotton wool of commerce thus sterilized answers all the needs of surgical use; the occasions for the use of the prepared cotton, known as absorbent cotton, are very rare.

Protecting Sheets and Towels.—Much value attaches to the use of sterilized sheets and towels to be used as covers for tables upon which instruments or other appliances are to be laid, for enveloping those parts of the patient's body not necessarily exposed, and for placing systematically around the area of operation to ensure a sterile environment for the operative procedures. These should be provided in abundance, sterilized by steam, or by soaking for twenty-four hours in a solution of corrosive sublimate, 1:2000.

PRECAUTIONS TO BE OBSERVED BY SURGEON, ASSISTANTS AND NURSES.

The most perfect aseptic environment and armamentarium may be rendered futile by the lack of thoroughness in securing personal disinfection upon the part of those having to do with the making or dressing of a wound, or by their lack of care to avoid contamination during the progress of their work. Every object or surface not known to have been recently sterilized is to be regarded as infected, and any contact with such must be followed by the resterilization of the hand or instrument or dressing at fault. It is important, therefore, that in matters of personal toilet and of clothing regard be had to the diminishing to the lowest possible degree the difficulties of sterilization and the dangers of contamination. In former days thought was given to the protection of the person and clothing of the surgeon from becoming soiled by the blood and discharges from a wound; in the light of present knowledge the problem has been changed to the protection of the wound from infection carried by the clothing and the person of the surgeon.

The outer clothing of the surgeon and his assistants must be sterile. This may be accomplished by putting a sterilized gown over the ordinary clothing; a better way is for the surgeon to remove his outer clothing and substitute therefor a special sterilized suit of linen or other washable material. My own practice, when about to deal with wounds, is to remove the outer clothing and the shirts, and to put on a pair of recently

laundered linen trousers, a short-sleeved gauze undershirt, and a high-reaching apron. After the purification of the hands has been completed and the patient has been made ready, this apron is replaced by a sterilized linen jacket or blouse (Figure 27).

Female nurses acting as assistants, or charged with the care of

FIG. 26.—Sterilizable dress for nurse in operating room.

FIG. 27.—Sterilizable dress for surgeon's use in operating room.

sponges or instruments, should also be as scrupulous in the wearing of sterilized apparel as the chief surgeon himself. The costume which experience has evolved for the use of my own nurses is shown in Figure 26.

The sleeves of all operating jackets, gowns or dresses should not reach the elbow, but should leave exposed the entire forearm. In addition to

the cleansing received in the general laundry, these garments should be freshly sterilized by steam just before being used.

Some minor points of personal toilet are not too insignificant to be considered in this connection, such as the length of the hair of the head, the wearing of a beard, and the trimming of the finger-nails. The surgeon should be a particularly "well-groomed" man; the hair should be kept short and as free as possible from dandruff. In this particular a bald-head has its advantages. It is the practice of some to cover the hair with a sterilized cap, and in the case with persons having long hair, as a female nurse for instance, such a precaution is wise. For the surgeon it is ordinarily unnecessary, for the simple device of wetting the hair will prevent particles of dust from being shaken from it into any wound over which the head may be held. Beyond possibly a mustache, a surgeon should not wear hair upon his face. The proximity of a beard to a wound is to be deprecated as an unnecessary strain upon the practice of prevention of wound infection.

The finger-nails should be kept cut short, so that no accumulations of material in the space beneath them can be possible, and the bristles of a hand-brush can reach every point. In the process of hand-cleaning, after thorough soaking and scrubbing, the subungual space should be further cleaned by scraping with a suitable blunt metal or wooden instrument to remove the infected mass of epithelium, sebum, and foreign matter which tends to persist under any overhanging nail edge. No finger ring should be worn.

The *sterilization of the hands and forearms* presents great practical difficulties. They are always contaminated, not only from the innumerable contacts with contaminated materials incident to the ordinary affairs of life, but also from the pyogenic staphylococci which have their natural habitat in the follicles of the skin. After vigorous and prolonged scrubbing with brush and soap and hot water, and immersion for some minutes in a solution of corrosive sublimate, repeated tests have shown that often there still remain upon the hands living bacteria. It has been pointed out, also, that although a perfect superficial sterilization of the skin should have been effected, yet in the course of a prolonged operation deeper layers of epidermis, containing organisms, may become exposed, so that a hand, which was in a satisfactory condition

at the beginning, may not be so at the end. In consequence of this some surgeons, in addition to as complete a mechanical and chemical disinfection of the hands as they can make, draw on sterilized gloves as a further protection. An increased immunity from even trivial wound-infection is claimed to have followed the adoption of the practice of glove-wearing, so much so as to render the inconveniences incident to it of little moment. It remains indisputable, however, that the uncovered hand can be sufficiently disinfected to admit of its prolonged contact with a wound without infecting it, and a consideration of the best practicable means to secure disinfection of the hand must ever be of importance.

The most important element in hand-purification is the mechanical process of scrubbing them with brush and soap and water. The brushes should be of stiff bristles, large enough to afford a good grasp, and should be sterile. They may be sterilized by steam, or by prolonged immersion in sublimate solution. After each use they should be rinsed out and resterilized before being again used. The water should be as warm as can be comfortably borne. A running stream from the water-supply tap is to be used if it is possible to secure it; if water in a bowl must be used, it should be repeatedly changed during the scrubbing process, and affusions from a pitcher should close the process. The character of the soap is of importance that unnecessary irritation of the skin may be avoided. In my own work I have had much satisfaction from the use of a fluid soap prepared according to the formula of Hanks, which is as follows:

R. Saponis viridis, opt.....℥iii
Alcoholis,
Glycerinæ,
Aquæ.....aa ℥i
Olei bergamot..... ℥i
Misce.

In scrubbing, while especial attention must be given to the spaces under and about the nails, the entire forearms and hands must also be vigorously treated. From five to ten minutes should be devoted to this

process, the longer the better, the lather being washed away from time to time in the flowing hot water. This scrubbing should be followed by washing with strong alcohol during a period of from two to three minutes. By this all remnants of the soap are removed and any oily secretions persisting in the mouths of the follicles and possibly enveloping micro-organisms are dissolved. Finally the hands and forearms up to and including the elbows are immersed in corrosive sublimate solution, 1:2000, for from three to five minutes. At the end of this time the surgeon may proceed with his work. Should the hands thereafter come accidentally in contact with a non-sterile object or surface, they should be again immersed for a time in the sublimate solution; and even apart from such accident, they should from time to time during the progress of a prolonged operation be immersed in the disinfecting solution.

As a method of securing a yet more reliable disinfection, the following method for the successive use of different bactericidal agents is largely practised. Its value must be due entirely to the prolongation of the process, for the individual agents are weaker bactericides than the corrosive sublimate.

The hands, after being mechanically cleaned, are immersed in a hot saturated solution of permanganate of potash until stained a deep brown. They are then immersed in a warm saturated solution of oxalic acid until completely decolorized; finally the oxalic acid is removed by rinsing in sterile water or lime-water.

If the surgeon elects to cover his hands with sterilized gloves, the preliminary disinfection of the hand should be no less thorough than if it was alone to be trusted to. Gloves of rubber, of linen and of cotton material have been used. They should be sterilized by boiling. The following is the glove technique used by McBurney: Gloves of pure rubber are first thoroughly washed with soap and hot ammoniated water, and then boiled for fifteen minutes in a one per cent. soda solution. They are then enveloped in a sterilized towel till used. Operator, assistants and nurses put on a fresh pair for each operation. If the hands are dried upon a sterile towel and then well rubbed with dry sterilized starch the gloves can be drawn on quite easily, even when their interior is moist. If the gloves are distended with sterile fluid the hands enter readily. While in use, blood or other fluids can be rapidly washed off

as often as one chooses, or a fresh pair of gloves can be put on at any moment in case of accidental contamination.

The patient's skin in the vicinity of a wound, or in a region in which a wound is to be made, requires scrupulous care and much attention to secure its disinfection. A wide area should be thoroughly scrubbed and shaved, and then, if time allows, should be macerated for from twelve to twenty-four hours under a compress wet with boro-salicylic solution. About two hours before the expected operation this compress should be removed and the sodden area should again be thoroughly scrubbed; after which a compress wet with sublimate solution, 1:2000, should be applied and kept on until after the patient has been anæsthetized and placed on the operating table; here a final scrubbing is done, followed by vigorous sponging of the region with ether, and lastly a free douching with the sublimate solution. The surface is then ready for incision. In cases of emergency the preliminary boro-salicylic soaking must be omitted, and the period for the application of the bichloride compresses reduced as the exigencies of the case may require. After the regional disinfection of the skin has been done an additional wide area of the skin surface should be covered with sterilized towels to lessen possibilities of accidental contact infection of hands, instruments or dressings. In many cases the covering of the entire body by one or more sterilized sheets is desirable.

The agencies which nature provides for the spontaneous arrest of hæmorrhage include, therefore, the following:

1. Immediate diminution in the size of the opening by the intrinsic contraction or collapse of the walls of the injured vessel.
2. Immediate and direct compression from without by contraction of surrounding tissue.
3. Secondary diminution in the force and volume of the blood current by heart faintness.
4. Temporary plugging by coagulation of the escaping blood.
5. Permanent occlusion by the exudation and organization of plastic material at the seat of the wound in the vessel.

The agencies which the surgeon likewise will find of benefit must derive their value either from the compression they produce, the contraction of the vessels they excite, the interference with the blood supply they accomplish, or the increased coagulability of the blood they occasion.

The means for arresting hæmorrhage naturally divide themselves, therefore, into means of *direct vascular contraction,* of *compression,* of *plugging* the open orifice of the vessel, and of *interruption to the blood current.*

Means of Direct Vascular Contraction.—This class includes contact of atmospheric air, cold and hot applications, and such local irritants as iodine, alcohol, and turpentine.

Exposure to Air.—The contraction of soft parts when exposed to the air is very marked, and the continued exposure of a bleeding surface to cool air produces a strong hæmostatic effect, which is increased if the air is kept in motion as by a fan. When a wound is filled with coagula, underneath which bleeding is still taking place, the thorough removal of the clots and the exposure of the bleeding points are often speedily followed by the cessation of the hæmorrhage. In all cases where there is present hæmorrhage, the first duty of the surgeon is, if possible, to fully and clearly expose the bleeding-point by the removal of whatever clots, compresses, or bandages may have previously accumulated in or about the wound. Should the mere exposure to the air not be sufficient to cause the hæmorrhage to cease, it is in the best position to receive the benefit of other applications. Where the possibility of recurrence of hæmorrhage

in a wound is to be feared, the free exposure of the wound-surfaces to the air for some hours furnishes the most reliable means of guarding against it. Though the wound be not closed until after many hours, the process of healing may yet continue without material disturbance, and union by first intention be secured.

Cold as a hæmostatic has always been recognized as of great value. It may be applied by irrigating the wound with cold water, by applying sponges or compresses wrung out of cold water, by the application of small pieces of ice to the bleeding surface, or by enveloping the part in bags containing pounded ice. Although cold, thus applied, causes the soft parts to contract and the blood-vessels to shrink, its application for any length of time tends to increase shock, and to depress the vitality of the wound-surfaces, and thus to diminish the vigor of the subsequent repair of the wound. The after effect of the cold is to lessen the tone of the capillaries and predispose them to inflammatory conditions. The use of cold applications for hæmostatic purposes is therefore to be resorted to only in exceptional cases in default of other resources.

Hot water is even more efficient as an hæmostatic than cold. It combines in an eminent degree the properties of stimulating the contraction of the soft tissues of the exposed surface, and of exciting the vital contractility of the vessels both directly by contact, and indirectly through the vaso-motor nerves. It produces a permanently stimulating effect upon the vitality of the surfaces to which it is applied; it favors primary union in the wound; and in no class of cases is its value more marked than in those of threatened shock and of exhaustion from hæmorrhage. The temperature of the water should be as great as can be borne by the hand without pain, from 125° to 139° F. The most effective means of applying it is by means of compresses of muslin or linen, or towels of size sufficient to cover the whole wound-surface, that all parts may experience the effect of the application simultaneously. To obtain the full effect, it is important that one compress be quickly succeeded by another till permanent arrest of the bleeding is secured.

Hot water answers the requirements of a wound-application more perfectly than any other agent. The simple precaution to free it from hurtful organisms before it is used is alone needed to make it entirely unobjectionable.

Iodine added to hot water increases its hæmostatic effect, while it also disinfects it. Sufficient of the iodine may be poured into a basinful of water to make the latter a light sherry color. A sponge wrung out of this lotion (made with hot water), and held to a wound for a minute, will often completely check all oozing of blood.

Alcohol excites to action the contractility of the vessels and the perivascular tissues. It may be applied on a sponge pressed upon the bleeding surface.

Turpentine excites a peculiarly energetic contraction of divided capillaries. It may be applied on bits of absorbent material pressed against the bleeding points. It is a heroic remedy causing severe pain, and exciting severe inflammation in the wound and its vicinity.

MEANS OF COMPRESSION.—Compression may be accomplished by agents that either stimulate the wounded tissues to more energetic contraction, or that may exert direct mechanical pressure upon the bleeding surfaces.

The first class of agents includes again atmospheric air, cold and hot applications, and certain irritants, since these agents cause the surrounding tissues to contract with the same energy as they do the bleeding vessels. The contraction of the perivascular tissues is a very important element in accomplishing the spontaneous arrest of bleeding. The range of application and the value as hæmostatics of the agents which have been considered as stimulants to contraction of the vessels directly is thus greatly increased by their effect upon the surrounding tissues, through the contraction of which physiological compression of the vessels is secured. To supplement this, however, means of compression, applied from without, are necessary whenever the size of the vessels is too great to admit of their control by physiological means, or the wounded tissues are non-contractile. This is supplied by some form of mechanical pressure, the consideration of the varieties of which is next to be taken up.

MECHANICAL PRESSURE.—Properly applied pressure is sufficient to control any hæmorrhage. It may be applied by means of compresses, tampons, bandages, the fingers of the surgeon, needles thrust into the tissues, forceps, and ligatures. The method of its application will depend on the character and anatomical relations of the bleeding vessels; when the bleeding comes from several points, or when it is a general

oozing, which persists notwithstanding the use of means to excite tissue contractility in the wound, a compress is of great value.

Compresses may be made of any substance that permits of being formed into a firm pad of proper size to be introduced into the wound. Folds of gauze or other cloth are generally available. Iodoform gauze is especially valuable for use as a hæmostatic compress on account of its double action in favoring vascular contraction and in restraining bacterial activity. All clots should be turned out of the wound, and the first layer placed directly upon the orifices of the bleeding vessels. Each additional layer of the compress should be larger than the preceding, as it is built up till it projects above the surrounding integument. The whole should then be firmly bandaged. In cases where compresses are applied to wounds of a limb, the roller-bandage should invariably first be applied at the distal extremity of the limb, and carried up the limb, over the compress and above it for some distance.

Compresses are to be considered only as temporary expedients, for their use is in violation of every principle of wound-treatment except that of hæmostasis. At the earliest moment they should be removed from the wound. If the wounded vessels are of such size as to render a recurrence of the hæmorrhage from them likely to take place, they should be secured by ligature as soon as the necessary procedures are practicable.

In wounds of slight extent sufficient compression to control bleeding may often be exerted by bringing the surfaces into apposition by sutures, and then supporting them by compress and bandage applied upon the surface.

Tampons are plugs which are crowded into cavities, such as the nares, the rectum, or the vagina, from some part of whose walls bleeding is taking place. They act by the direct pressure which they exert upon the bleeding vessels.

Hæmorrhage from larger arteries and veins is best controlled by compression limited to the bleeding vessel, and applied directly to it. The finger of the surgeon instinctively applies itself for the purpose of making such compression upon the orifice of the severed vessel, and, for immediate temporary hæmostasis, by its intelligence, its power of properly graduating the compression to the needs of the case, and the minimum amount of disturbance which it inflicts upon the adjacent tissues, is em-

ployed with great advantage. When prolonged compression is needed, or several vessels require attention, other agents are required. Those that are employed are needles, forceps and ligatures.

Acupressure.—Needles or pins may be thrust into the tissues so as to compress the extremity of a bleeding vessel, either by transfixing the tissues when in a state of tension, and securing pressure upon the vessel against the needle by the force of the elastic recoil of the tissues, or by affording a solid substance against which pressure can be made by other agents. By the pressure of the pin the vessel is not lacerated, nor the vitality of any portion of it destroyed, and before it can become a cause of suppuration the pin may be withdrawn and the wound left free from the presence of any foreign body as an irritant, or mechanical impediment to repair. The compression with pins need not be prolonged for more than twenty-four hours upon vessels of small calibre, nor upon such vessels as the brachial or superficial femoral for more than forty-eight hours.

FIG. 28.—Simple method of applying acupressure.

Any smooth sharp-pointed pin of sufficient length to transfix the tissues suffices for use in the practice of acupressure. A large shawl-pin, by its smooth, globular, glass head, stoutness, length, and smoothness, answers perfectly for the purpose.

The simplest method of applying acupressure is to pierce the tissues so as to bring the point of the pin out on the surface of the wound close to the side of the bleeding vessel, and then, having carried it over the vessel, to lift its head, so as to depress strongly the point and thrust it onward into the tissues, close to the vessel on the other side. (See Figure 28.) The force of the pressure exercised by the pin thus applied will depend upon the amount and the elasticity of the tissue transfixed by it, and by the resisting character of the tissue against which the pressure is made. It is most effective when the pin is carried through the skin, so that the latter is stretched between the points through which the pin passes, and when the vessel is pressed against a bone. When the skin is

transfixed, and still the pressure is not sufficient to arrest the hæmorrhage, the constriction can be increased by throwing a ligature tightly around the pin, on the outside, as in the operation for harelip. When the tissues are lax and do not afford sufficient counter-pressure, their resistance can be increased by twisting them, and by giving the pin different

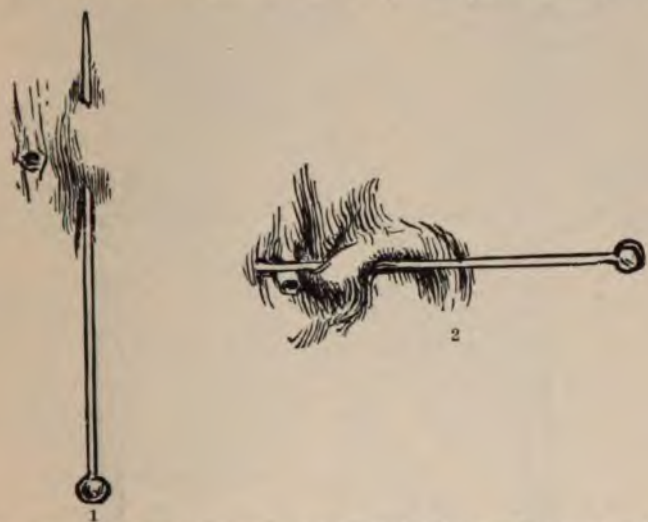

FIG. 29—Acupressure with twist of tissues. 1, pin introduced parallel to vessel. 2, pin rotated through a quarter-circle and, after having been carried over vessel, thrust into tissues.

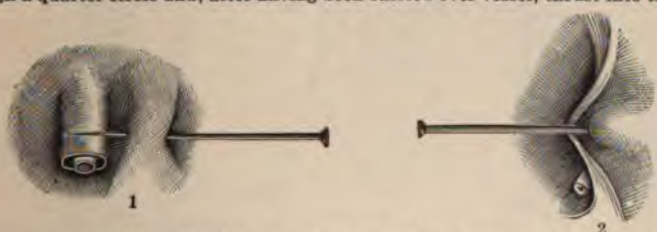

FIG. 30.—Acupressure with twist of tissues. 1, pin introduced transversely to vessel, its point ready to be thrust into tissues on opposite side. 2, pin entered and reversed, twisting tissues and compressing vessel.

directions in different parts of its course as it is inserted. Two methods of accomplishing this are illustrated in Figures 29 and 30.

Other variations in the method of applying acupressure may suggest themselves according to the particular relations of the bleeding vessel.

Forcipressure.—A bleeding vessel may be seized and compressed by suitable forceps, and not only the temporary but also the definitive arrest of the bleeding be secured without other agents. The *serres-fines* (Fig-

ure 31) and *serres-fortes,* or *compressiv-pincetten* (Figure 32) of the older surgeons, used for the temporary compression of bleeding vessels, the elastic recoil of their branches when separated being the force relied upon

FIG. 31.—Serres-fines.

FIG. 32.—Serre-forte, or compressiv-pincette.

for pressure, were inconvenient by reason of their small size, and unreliable from the feebleness and variableness of their elastic spring. The hæmostatic forceps of Péan, Koeberlé, and Wells are alike in substituting for the uncertain recoil spring of the old instruments the force of

FIG. 33.—Hæmostatic forceps of Péan.

FIG. 34.—Hæmostatic forceps of Spencer Wells. ¾ size.

direct pressure exerted through long and strong, though slender, levers as handles, which when closed are locked by an automatic catch. Figure 33 shows the model of Péan, from which that of Koeberlé does not differ

in any essential respect; Figure 34 that of Spencer Wells. A very large number of different models and sizes of these forceps or clamps have been devised to meet the requirements of different conditions and loca-

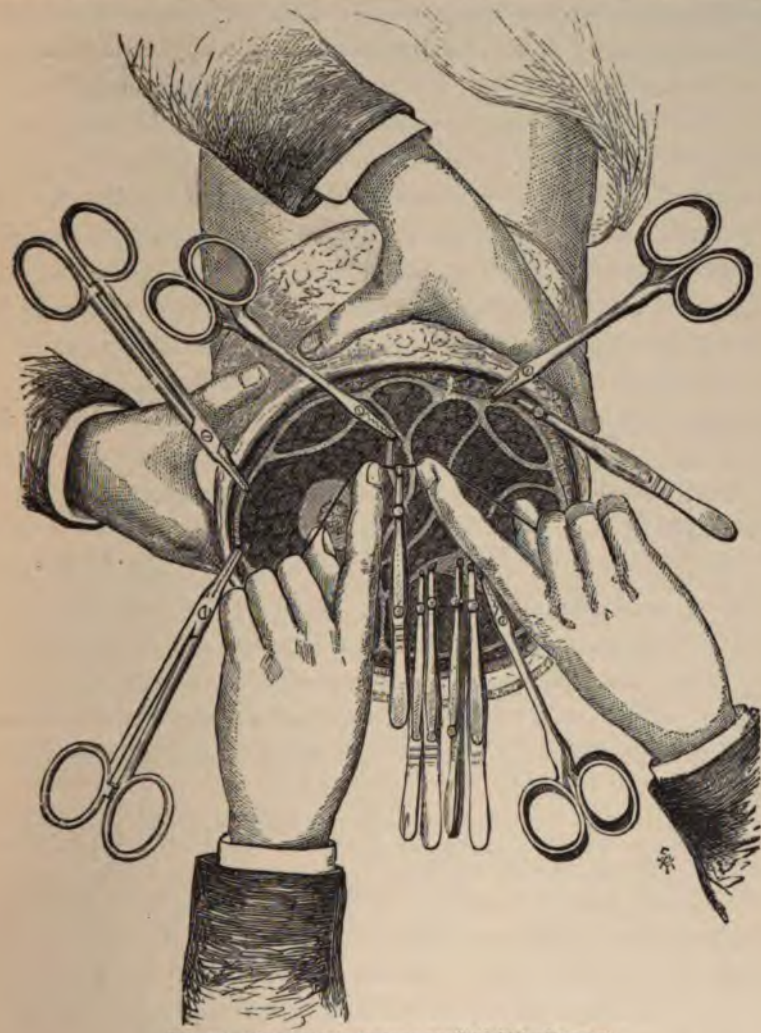

FIG. 35.—Hæmostatic forceps applied (*MacCormac*).

tions, and their use has become a very important part in modern surgical technique.

In seizing a bleeding vessel with these forceps no effort need be made to exclude fibres of surrounding tissue if the vessel be small.

The length of time during which the forceps should remain in place in order to secure permanent hæmostasis varies much. Those which have been applied upon the arterioles of the skin, connective tissue, and muscles, and upon veins, except in case of the great venous trunks, may usually be removed in a few minutes after their application. Forceps placed on arteries of medium size may be withdrawn from six to twelve hours after the operation. Upon the main arteries of the limbs, including the femoral, they should be left from two to four days. In operation wounds they find their most valuable field by reason of the time and blood that they economize through the facility and certainty of their immediate application to each vessel that is wounded. In large operations, as in an amputation of the thigh, or the extirpation of a large tumor, though many forceps may have been applied and remain hanging from the wound-surfaces, in the majority the hæmostasis will prove to have been definitive by the time the operation is completed, so that the forceps may then be withdrawn without need of other means to maintain closure of the vessel. Figure 35 shows the manner of their use for controlling hæmorrhage in the course of operations.

These forceps, when left in wounds, are easily supported by the dressings so as not to drag upon the tissues; rarely do they cause any distress to the patient, who becomes aware of their presence only when they are withdrawn. When removed they should be taken away one by one with care, and, as soon as it shall have become certain that the vessels which they were compressing no longer bleed, the dressing should be made as usual.

The application of such forceps upon tissues most prone to resent interference has not been productive of harm.

In all cases where the application of a ligature is impracticable or undesirable, forcipressure may replace advantageously most of the other means available in such cases. It may be used so as to shorten much the duration and danger of operations, and, by leaving no foreign body in the wound, favors repair by first intention.

Ligation.—The last method remaining to be noticed which is available for exerting compression upon bleeding vessels is that of encircling it with a thread thrown about its exposed extremity, and tying it firmly with a secure knot. This constitutes ligation. Though it would seem

that this method should have instinctively suggested itself for controlling the bleeding from a severed vessel, and though traces of a theoretical knowledge of it as a possible means for controlling hæmorrhage are discernible in the writings of Galen, Celsus, Avicenna, and Albucasis, there is no evidence that it was ever practised until it was used by Paré in amputations in the sixteenth century.[1]

The method of Paré was to seize the vessels with suitable forceps (a thing not difficult to do—he says—because the blood can be seen spouting from them), draw them out from the flesh into which they have retracted and become hidden, and then tie them with a stout double thread. Although Paré thus brought this procedure very nearly to the degree of perfection that it has now attained, the prejudices of his contemporaries, and the erroneous methods of practising it followed by his pupils, caused it to rapidly fall into discredit, so that a hundred years later the surgeons of the Hôtel-Dieu were still to be found always employing the cau-

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[1] The introduction of the practice of ligating bleeding vessels marks the first great advance made in the treatment of wounds in the history of surgery. During the ages previous to the time of Paré the actual cautery had been the principal means of staunching traumatic hæmorrhage. Paré himself mentions his previous use of the cautery as "a thing very horrible and too cruel to be mentioned" (*chose très horrible et cruelle seulement à raconter*, book x., chap. xxvi.), and, in the same chapter, relates his own first experiment in the use of a ligature to close the vessels after amputation of a limb, as follows: "Now I advise the young surgeon to abandon such cruelty and inhumanity in order the rather to follow this method of mine, with which it has pleased God to acquaint me without my ever having seen it done by any one, nor spoken of, nor mentioned, except by Galen, in the fifth book of his *Method*, where he writes that it is necessary to tie the vessels on the side toward their roots, which are the liver and the heart, in order to staunch the great flow of blood. Now, having many times made use of this way of serving the veins and arteries in recent wounds which bled, I thought that it would be well to do as much in the extirpation of a limb. Having conferred on this matter with Stephen de la Rivière, Surgeon in Ordinary to the King, and with other surgeons from Paris, and having declared to them my opinion about this, they advised that we should make the experiment on the first patient that should be offered, the more since we could have the cauteries all ready for use in case the ligature should fail. This I practised on the spot on several with very good result; and again, some days later,

tery after amputations.[1] The supposed dangers from secondary hæmorrhage, from too rapid fall of the ligature, if applied directly to the vessel, caused Paré's most distinguished pupil, Guillemeau, to abandon the simple method of his preceptor and to practise, instead, mediate ligation, enclosing a mass of adjacent tissue, together with the vessel, in the ligature. The effect of such a procedure was to assist the more surely in bringing the use of the ligature into disrepute. Excruciating pain, muscular spasms, and violent local inflammations were provoked by its use in such a way, while the speedy loosening of the ligature, as it cut the interposed flesh, in a few days, often determined a mortal hæmorrhage. Eight out of every ten cases of amputation thus treated died. Mediate ligation in its turn, therefore, fell into discredit, and was either abandoned almost entirely or used in combination with styptics and escharotics. The surgical world in the early part of the eighteenth century was employed in a search for hæmostatic agents, but the fear of a recurrence of the bleeding when the ligature should become detached still deterred

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in the person of a postilion servitor from Brusquet, named Pirou Garbier, whose left thigh was amputated four fingers above the knee for an inflammation which had supervened upon a fracture.

"In conclusion I counsel the young surgeon to abandon this miserable way of burning and roasting (unless some remnants of gangrene compel it), admonishing him to no longer say, 'I have read it in the writings of the ancients, I have wished to act in accordance with the teachings of my old fathers and masters, following whose practice I cannot err.' This I grant, if thou wilt listen to thy good master, Galen, in the passage already alluded to, and to those like it; but if thou wishest to stop with thy father and thy masters for authority for bad practice, being willing to always continue therein, doing just the same as is usually done by them in all things, thou shalt render an account for it before God, and not before thy father or thy good masters, who treat men after so cruel a fashion."—*Œuvres complètes d'Ambroise Paré, tome* ii., p. 230. Ed. Malgaigne.

The date at which the adoption of the practice of ligation was made by Paré is fixed approximately by Malgaigne to have been about 1560, since the edition of his works published in 1552 mentions only the cautery as a means of arresting hæmorrhage, and that of 1564 contains for the first time mention of the ligature.

[1] Manec: *Traite de la Ligature des Artères*, p. 2. Paris, 1836.

surgeons from its use until the powerful authority of Sharpe,[1] in England (1760), and of Desault, in France (1780), restored it to confidence and brought it again among the acknowledged resources of wound-treatment.

Wide and flat ligatures, their size proportioned to the volume of the vessels, were at first deemed essential, lest the vessel should be too rapidly cut through. It remained finally for the present century to demonstrate, by the experiments of Jones,[2] that a small, round ligature was the best form to use in all cases for the arrest of hæmorrhage. The conclusions of Jones having been accepted and put in practice by Abernethy and Astley Cooper, the stout thread of Paré was restored, and the original method of that surgeon, after a lapse of two hundred and fifty years, became again the rule of surgery. Nevertheless, it still remained that the application of a ligature, however done, introduced a foreign body into a wound, and hence was to be deprecated, on account of the disturbance of the repair of the wound which it produced, both directly and indirectly, for its final separation and removal from the wound necessitated a process of ulcerative absorption of the vessel which it constricted.

The part of the vessel beyond the ligature, when it is applied upon the cut extremity, is also deprived of nutrition, and, dying, must be thrown off as a slough. Suppuration is the necessary attendant of these conditions, and when, as is usual, the ligature thread is left hanging from the wound until the knot has ulcerated itself loose, there is maintained a suppurating sinus throughout its track which favors the development of serious septic conditions in the wound.

Practically the evils resulting from these unfavorable conditions, incident to the use of a ligature, are overcome in the great majority of cases by the natural reparative powers of the body, and ultimate healing

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[1] This surgeon, in his Critical Enquiry into the Present State of Surgery, formally advocated the employment of the ligature for the arrest of hæmorrhage from wounded arteries, in preference to styptics or the cautery, on the ground that "it was not as yet universally practised amongst surgeons residing in the more distant counties of our kingdom."

[2] A Treatise on the Method employed by Nature in suppressing the Hæmorrhage from Punctured and Divided Arteries, and on the use of Ligatures. By J. F. D. Jones, M.D. 8vo. London, 1805.

is secured after a more or less prolonged period of suppuration and contest with inflammatory and septic accidents of more or less severity.

On account of the interference with healing produced by the ligature, importance has been given to those substitutes for it which in any degree diminish the elements of disturbance produced by the means needed for fulfilling the supreme indication of arrest of hæmorrhage. It is this which has given to acupressure and forcipressure, and torsion—a method yet to be noticed—their chief importance. No substitute for the ligature, however, has been able to obtain a permanent place in the confidence of surgeons, and it will undoubtedly always remain the chief resource for arresting hæmorrhage from vessels of any size. It is simple and easy of application, it is certain as a hæmostatic, and the materials for it are to be found in every place.

Of far greater importance than the attempts at providing a substitute for the ligature have been the results of studies to improve the ligatures themselves, striving to secure for the use of the surgeon a material strong and efficient for the compression of the vessel, as long as needed, unirritating while it is performing its work, not hindering immediate union, and, finally, capable of spontaneous absorption by the tissues in which it has been buried.

A thread of any material which can be tied with sufficient firmness and closeness to effectually strangulate a vessel, may be used as a ligature, and when the emergency presses there may be no choice left as to a selection. For general use silk thread—round, smooth, well twisted, uncolored, and sufficiently strong to stand considerable traction—has been preferred. In order to reduce to the minimum quantity the amount of tissue to be removed by ulceration, it is important that the thread be no larger than is necessary to give it the strength required to stand the strain put upon it when it is tied. For small vessels the thread need not be larger than common sewing-silk; for larger vessels, as the femoral, iliac, or axillary arteries, a somewhat stouter thread—saddler's silk—is needed. After the ligature has been tied, it has been customary to clip off one end close to the knot, and to bring out the other at the nearest angle of the wound, or, if that was too remote, at any more convenient point, where it has been necessary to permit it to remain until the ligature has become disengaged from the vessel within by its ulcerative division. To ac-

complish this, a period of from three days to three weeks, according to the size of the vessel, has been necessary. The amount and nature of any other tissue that may have been included in the ligature together with the vessel will also influence the time of its detachment. With the idea of lessening the evils consequent upon such a prolonged residence of an irritating thread, Physick,[1] of Philadelphia, in 1814, began to use ligatures made of leather, with the expectation that such animal material would be less irritating, and would undergo softening and absorption. In the year previous, 1813, Dr. Thomas Young, of Edinburgh, in his "Introduction to Medical Literature," wrote: "I have often wished to try ligatures of catgut, which might be absorbed," but no record of any such test having been made by him is given.

After Physick, Jameson, of Baltimore, adopted the animal ligature, using buckskin cut into narrow strips and firmly rolled. These, after numerous experiments and clinical observations, he declared to be decidedly superior to all other ligatures,[2] and, before his death, had applied

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[1] The following is Physick's own report of his use of animal ligatures in a communication by him to The Eclectic Repertory, 1816, vol. vi., p. 389:

"Several years ago, recollecting how completely leather straps, spread with adhesive plaster, and applied over wounds for the purpose of keeping their sides in contact, were dissolved by the fluids discharged from the wound, it appeared to me that ligatures might be made of leather, or of some other animal substance, with which the sides of a blood-vessel would be compressed for a sufficient time to prevent hæmorrhage; that such ligatures would be dissolved after a few days, and would be evacuated with the discharges from the wound. Under this impression I requested Dr. Dorsey to try the experiment on a horse by using a ligature of buckskin. This was found to answer every purpose and came away in a few days.

"Dr. Dorsey, in several operations in which I have assisted, has used ligatures of French kid, which he finds stronger than any other leather. He has it cut into narrow strips, stretches them, and peels off the colored polished surface. No hæmorrhage has taken place in any instance, and the ligatures are found dissolved at the end of two or three days."

From this period—1816—he continued to employ animal ligatures almost exclusively up to the time when he left off operating. Memoir of Physick, by Randolph, p. 85.

[2] Gross: System of Surgery, 1882, vol. i., p. 657.

them to all the accessible arteries of the body.[1] Animal ligatures of various kinds were occasionally used by other isolated surgeons during the fifty years which followed Physick. Silk-worm-gut by McSweeney, in 1818,[2] and by Fielding, in 1826;[3] catgut, by Sir Astley Cooper, and fibres from the sinews of the deer, by Eve, of Nashville, were thus used; but not until 1869, when Lister published the results of his experiments with catgut ligatures,[4] and incorporated them into his method of antiseptic wound-treatment, did the full value, and range of the use to which animal ligatures could be put become generally recognized. Equally with catgut the parallel strands of connective tissue which make up the tendons of different animals have been found to answer an excellent purpose. Though these tendinous ligatures have the advantage of being much stronger than catgut, equal weights being used, and of softening less quickly, yet properly prepared and seasoned catgut may always be safely trusted; and since it is a staple article of commerce, to be had all over the world in abundance, comparatively cheap, and easily prepared and manipulated, it has maintained itself as the kind of animal cord best adapted for general use as a ligature, and hence requires more extended notice.

Catgut Ligatures.—Catgut is the submucous cellular tissue of the intestines of young lambs, which, after having been cleansed in an alkaline bath and bleached by sulphurous acid, is twisted into a cord and dried. As it comes from the maker it is entirely unfit for use as a ligature, for when bathed in the secretions of the wound it quickly becomes so soft and pulpy that a knot will not hold. By suitable preparation or seasoning, however, its qualities may be so altered that immersion in blood-serum will no longer make it pulpy, but that it will continue to retain its form and tenacity for a somewhat prolonged period, during which its removal

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[1] Agnew's Surgery, 1878, vol. i., p. 173.

[2] Experiments in Favor of a New Substance for Tying Arteries, and for Suture. Edinburgh Medical and Surgical Journal, 1818, vol. xiv., p. 597.

[3] On the Use of a New Substance (Silk-worm-gut) for Securing Divided Arteries. Transactions Medico-Chirurgical Society, vol. ii., p. 340. Edinburgh, 1826.

[4] Observations on Ligature of Arteries on the Antiseptic System. Lancet, April 3, 1869.

is being slowly accomplished by the gradual erosion of its surface by the active tissue-cells by which it is surrounded. Thus compression of the tied vessel is insured throughout the whole time that the process of its repair is transpiring.

Different methods of sterilizing catgut have already been given, for which see Chapter VI.

After a catgut ligature is applied, the ends are to be cut off short, and the wound closed without any further attention being paid to the ligature. When a properly prepared gut is used nothing more is ever seen of the ligature. It is mechanically unirritating and if sterile produces no disturbance in the process of repair by its presence, and is ultimately removed by absorption in the course of the tissue metamorphoses that are incident to the normal life of the tissues in which it is embedded. An indefinite number of ligatures may be applied, according to the demands of speedy and perfect hæmostasis, in a wound without hindering its union by first intention. By its use one of the greatest hinderances to union by first intention has been removed, and the treatment of wounds greatly simplified. The portion of tissue included in the noose of the ligature does not die, nor does the external coat of the included vessel become divided or ulcerate. It is applicable in septic wounds as well as in those that are kept aseptic. It is only a little less easy to manage than silk.

Threads of *aseptic silk* may be used for ligatures in the same manner as has been described for catgut, and should be used rather than catgut whenever suspicion attaches to the absolute sterility of the latter, since the immediate sterilization of the silk by boiling is always possible. If the ends of the silk ligature are cut off close and the wound is sutured, primary union may be expected, the ligature becoming encysted, and gradually disintegrating and becoming absorbed. That such a favorable result should be secured demands the most perfect attention to all the details necessary to prevent wound-infection. In the presence of infection each knot and loop of the silk thread becomes an irritating body in the centre of a suppurating focus, and it is necessary either to expose it and remove it, or to await its slow extrusion by the gradual processes of suppuration and ulceration. Its presence at the bottom of a deep sinus may prevent indefinitely the closing of such a sinus. It is a frequent ex-

perience, also, that buried ligatures of silk, which have healed in primarily without provoking any disturbance, after some weeks, or even months, become the seat of irritation that terminates in suppuration, as the result of which they "work to the surface" or require to be cut down upon and removed.

Technique of Ligation.—The bleeding vessel must be seized by a suitable pair of forceps and drawn out from the tissues, among which it has retracted, sufficiently to permit it to be isolated and to be encircled by

FIG. 36.—Ligation of vessel in dense tissue (*MacCormac*).

FIG. 37.—Ligation *en masse* (*Esmarch*).

the ligature far enough back from its free end to guard against danger of its slipping off. The hæmostatic forceps (Figures 33 to 35) will probably have already been applied, and nothing better could be secured to facilitate the application of the ligature when desirable. It is essential that whatever forceps are used should hold the vessel firmly, and not be liable to become accidentally displaced, and that it should remain closed automatically when once it has been applied. A tenaculum may sometimes be used instead of a forceps for picking up a vessel when it is em-

bedded in dense tissues that do not permit its being readily drawn out. The sufficient isolation of the vessel from other structures may be generally effected without trouble; but this may not be practicable when the tissues have been matted together by previous inflammation, or where the natural density of the tissues prevents its being drawn out. Should the vessels be brittle from disease of their coats, it may be best also to tie

FIG. 38.—The reef-knot.

FIG. 39.—The surgeon's knot.

up with them a cushion of the soft parts. To accomplish this a curved needle, armed with the ligature, may be passed beneath the bleeding point through the tissues so as to include with the vessel a small portion of the adjacent tissue, as in Figure 36; a ligature thus tied cannot slip, and when catgut is used and the wound is kept aseptic no necrosis of the included portion will take place.

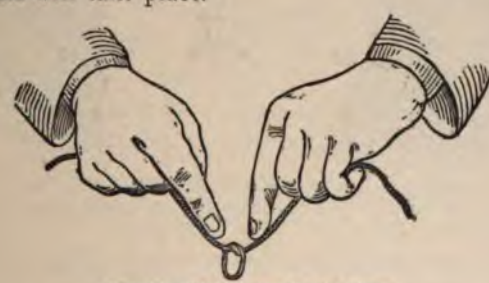


FIG. 40.—Tightening the ligature.

Figure 37 will suggest another method of accomplishing the same end.

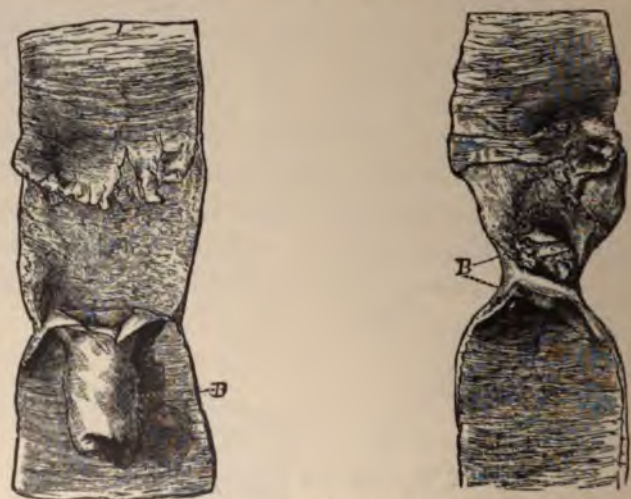
The ligature should be tied in a single reef-knot (Figure 38), in preference to the surgeon's knot (Figure 39) or the common granny-knot. It is necessary to use no more force in drawing the knot than is required to firmly and securely close the vessel, which may best be done by placing the index fingers upon the thread close to the point of application to the vessel (Figure 40) and through them making traction.

In ligating the larger arteries the knot should be drawn sufficiently

tight to cause the internal and middle coats to give way if the common silk ligature is used; but this is less necessary, though unobjectionable, if the catgut is used. When the catgut or the aseptic silk ligature is used, the ends should be cut off short, and the knot abandoned to itself; when the ordinary thread is used, one end should be clipped off quite close to the knot, and the other brought out of the wound.

MEANS OF PLUGGING THE VESSELS.—These include torsion, coagulants, and the actual cautery.

Torsion.—When the internal and middle coats of an artery are lacerated and separated from the outer coat, the elastic quality of the mid-

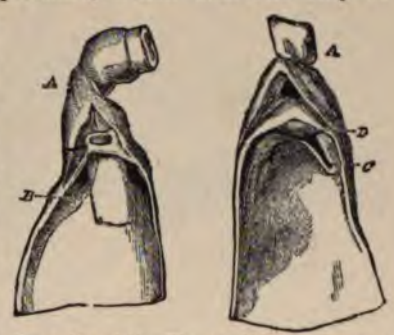


FIGS. 41 and 42.—Laceration and incurvation of internal coats of an artery from external injury (*Bryant*). B B, plugs formed by incurved internal coats.

dle coat causes it to become retracted and incurved, and thus to block up more or less completely the lumen of the vessel. (See Figures 41 and 42.) Arteries that are torn across, as in lacerated wounds, may be spontaneously closed to such a degree by this cause that no bleeding will take place from them, an entire limb being torn from the body without any hæmorrhage following.

This retraction and incurvation of the inner coats of an artery may be accomplished at will by sharply twisting the cut end of the vessel. The practice of this manœuvre upon a bleeding vessel constitutes "torsion."

The first systematic and intelligent application of torsion as a means of arresting bleeding is to be credited to the French school of surgeons of the early part of the present century, of whom Amussat,[1] Velpeau,[2] and Thierry,[3] nearly at the same time appeared as its advocates, each with a peculiar method of his own. To the elaborate memoir of Amussat, especial mention is due for the manner in which it developed and illustrated the principles on which the practice is to be based. Nevertheless it has never gained general confidence except for the closure of small arteries. More recently, however, it has been warmly advocated by Bryant, of London, who says:[4] "In a physiological point of view there is no method more perfect at command for the control of hæmorrhage than that of torsion; because, unlike acupressure, which uses one only of Nature's hæmostatic processes, or the ligature, which is a foreign body in a wound, and becomes a source of danger by undoing at a later what has been done at an earlier period of the case, it utilizes to the utmost all the physiological processes employed by Nature to prevent and arrest bleeding, and places the vessel in the most favorable position for them to take effect." To continue to quote from the same author (p. 302): "When an artery is closed by what is termed torsion, the inner coats are ruptured (Figures 43 and 44, B and C), and the outer (A), when not twisted off, closed by the twists to which it has been subjected. But the inner coats, instead of being simply divided in a linear manner, as occurs when the ligature is used, become ruptured, separated from the outer coat and incurved, their divided ends turning into the vessel, and in the most perfect examples forming complete valves, not unlike the semilunar



FIGS. 43 and 44.—Effects of torsion upon an artery (*Bryant*).

[1] *Séance de l'Académie Royale de Médecine*, July 16, 1829. *Archives Générales de Médecine*, 1829, tome xx., p. 606.

[2] *Journal universal et hebdomadaire de Médecine et de Chirurgie*, etc., 1830, tome i., p. 488.

[3] *De la Torsion des Artères*. 8vo. Paris, 1829.

[4] Practice of Surgery, p. 306. Philadelphia, 1879.

valves of the heart." As to the practical results of torsion, he says (p. 307): "After nine years' experience of the practice among vessels of all sizes (the femoral being the largest), I have had no mishap. I have further observed that wounds have united more rapidly and kindly—primary union being the rule; there has been less constitutional disturbance after operation, and consequently less liability to traumatic fever, pyæmia, and other complications, such as we are all too familiar with in the practice of surgery. At Guy's Hospital we have had two hundred consecutive cases of amputation of the thigh, leg, arm, and forearm, in all which

FIG. 45.—Torsion of brachial artery (*Erichsen*)

the arteries had been twisted (one hundred and ten of them having been of the femoral artery) and no case of secondary hæmorrhage."

To apply torsion Amussat recommended that the artery be drawn out for about half an inch by one pair of forceps; that it then be seized at its attached end by another pair of forceps (see Figures 45 and 46) to steady and hold it, while with the first pair of forceps the end be twisted off by about a dozen turns. According to Bryant, the vessel need be drawn out, as for the application of a ligature, and three or four sharp rotations of the forceps made. In large arteries, such as the femoral, the rotation should be repeated till the sense of resistance has ceased.

The ends should not be twisted off. In small arteries the number of rotations is of no importance, and their ends may be twisted off or not, as may be preferred. When the vessels are atheromatous or diseased, fewer rotations of the forceps are required, the inner tunics of the vessel being so brittle as to break up at once and incurve.

Torsion-forceps should have jaws broad enough to grasp the whole width of the vessel which is to be twisted, and their teeth should be blunt, lest they cut through the tissue of the vessel which they grasp.

In the experience of most surgeons torsion so often fails to close fully and definitely a bleeding vessel that it is rarely resorted to when a suitable catgut thread is at hand.

Coagulants.—The introduction into a wound of substances which by their combination with the effused blood shall form a firm tenacious coagulum to act as an efficient plug to the bleeding vessels is to be resorted to only as a last resource, when other methods are inapplicable or inefficient. Such reagents are irritants, the coagula formed act as foreign bodies, and their use destroys any possibility of union by first intention. Whenever used they are to be combined with direct compression, if possible. Wounds involving spongy tissues, and cavities or organs, such as the mouth, nose, and uterus, where it is impracticable to ligate the bleeding vessels, most frequently call for the application of coagulants. Previous to their application the soft coagula already present should be removed, the bleeding surface should be wiped as dry as possible, and then a compress saturated with the reagent should be firmly pressed to the bottom of the wound directly upon the bleeding orifices. The compress so applied should then, if possible, be secured in place by a bandage. Cavities, from the walls of which hæmorrhage is taking place, should be packed with absorbent plugs saturated with the reagent. Of

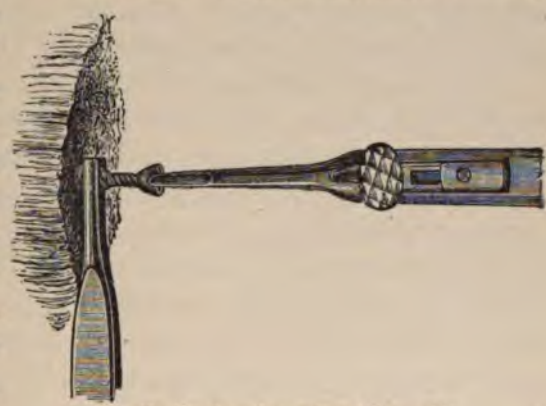


FIG. 46.—Torsion of an artery (*Esmarch*).

the multitude of substances that have been used as coagulants but two deserve mention, the subsulphate of iron (Monsel's salt) and alum, both of which are effective antiseptics as well as coagulants.

The subsulphate of iron may be used either in powder or in solution. A compress saturated with a lotion made of the officinal liquor ferri subsulphatis, diluted from four to six times with water, is a powerful hæmostatic, while it is less irritating than the stronger solutions. The iron produces immediately a dense, firm, and tough coagulum, that continues to shrink and harden for some time after its formation.

Alum is less powerful and instantaneous than the iron salt, but its astringent and coagulating effect is great. It may be applied in powder, or in saturated solution. The powder enclosed in gauze, so as to form a small bag, forms an efficient hæmostatic tampon, and is particularly suitable for plugging mucous canals.

The Cautery.—Iron heated to a dull red heat was the potential cautery of the ancients, which alone was relied upon to control arterial hæmorrhage. It is still frequently made use of for the control of bleeding from deep-seated vessels, and in the course of operative procedures upon very vascular parts, as the maxillary bones, the tongue, the neck, the uterus and the rectum. It is not only a coagulant but a caustic, and destroys the tissue to which it is applied, forming a thick eschar, which for a time effectually seals over the entire wound-surface. When it becomes detached as a slough after a few days, hæmorrhage frequently recurs from the ulcerated vessels. Care is to be exercised not to heat the cautery-iron above a dull red heat—the bright red or white hot iron consuming the eschar and leaving the vessels unsealed. In the emergency which calls for the cautery, the ingenuity of the surgeon will extemporize the needed cauting-iron. In the systematic arrangements for the prevention of hæmorrhage by the cautery in the course of surgical operations the ancient cauting-irons, with their furnace and bellows, have given place to the galvano- and thermo-cauteries.

Means of Interrupting the Blood-Current.—The force with which the blood-current shall reach the opening in a severed vessel may be modified by position, by compression of the vessel or its parent trunk between the wound and the heart, and by the internal administration of drugs which lessen the force of the heart's contractions. These means

are chiefly available as temporary resources until means of direct permanent hæmostasis can be devised.

Position.—The elevation of the limb, so as to add the force of gravity to the obstacles to be overcome by the blood-current, will materially diminish the force of the arterial supply to the more distant parts of the limb. It promotes also depletion of the veins. It is a resource not to be overlooked in case of wounds of the distal parts of the extremities.

Compression of the Vessel, or its Parent Trunk, between the Wound and the Heart.—This may be accomplished by one or more of the following ways: Forced flexion, digital compression, the tourniquet, the elastic bandage, acupressure, and ligation.

Forced Flexion.—When the forearm is strongly flexed upon the arm, in a muscular person, the brachial artery, in addition to being bent at an acute angle, is compressed both between the biceps and brachialis anticus muscles above, as they contract, and at the angle of flexion by the muscular mass there existing, while below, the first portions of its two main branches are compressed between the contracted muscles of the forearm. Sufficient compression may thus be exerted to completely interrupt the flow of blood through the arteries, and to make this an efficient means of assisting in the arrest of hæmorrhage from wounds of the distal parts of the upper extremity, and particularly from wounds of the palmar arches.

Flexion of the leg upon the thigh has but a very feeble effect upon the arterial current in the vessels beyond. By placing a compress in the ham and practising flexion a greater interruption can be produced. By strongly extending the foot, its dorsal artery may be compressed under the anterior annular ligament sufficiently to interrupt the current of blood through it.

Digital Compression.—When the bleeding is from a vessel which, either itself or its parent trunk, has in some part of its previous course passed superficially over a bony surface, the pressure of the thumb or fingers may be sufficient to compress it against the bone powerfully enough to completely interrupt the current of blood through it.

The common carotid artery may thus be compressed against the transverse processes of the cervical vertebræ by the thumb thrust between the larynx and the inner border of the sterno-cleido-mastoid muscle in such a manner as to make pressure downward and inward (Figure 47). The

facial, temporal, supraorbital, and occipital branches are all easily compressed by the finger of one familiar with their positions.

FIG 47.—Compressing the carotid artery (*Esmarch*).

The subclavian artery may be compressed, as it passes over the first rib behind the scalenus anticus muscle, by strong pressure made downward and inward into the fossa behind the clavicle at the outer border of the sterno - cleido - mastoid muscle. The unaided finger is, however, not strong enough to maintain the requisite force. A door-key, with its handle wrapped with cloth, is the classical substitute.

FIG. 48.—Compressing the brachial artery (*Esmarch*).

By raising the arm and making pressure along the anterior fold of the axilla, the axillary artery can be compressed against the head of the humerus.

The brachial artery may be easily compressed against the humerus, at the centre of the arm, by pressure made along the inner border of the biceps (Figure 48).

The radial and ulnar branches are readily compressed in the lower third of the forearm.

The abdominal aorta, when the abdominal walls are relaxed and the intestines empty, particularly in thin subjects, can be compressed against the vertebræ, by pressure applied a little to the left of the middle line at the level of the umbilicus. Macewen's method of applying and maintaining compression of the abdominal aorta is shown in Figure 49.

The femoral artery is most securely compressed, just below Poupart's ligament, against the iliopectineal eminence. It should be made with the two thumbs placed the one upon the other (Figure 50), and the pressure should be made upward and backward beneath the ligament upon the expanse of the eminence. The thickness of the intervening parts makes attempts at compressing the artery against the femur in the middle third of the thigh uncertain.

FIG. 49.—Compression of abdominal aorta (*Macewen*).

The posterior tibial at the inner ankle, and the dorsalis pedis upon the dorsum of the foot, are readily compressed by the fingers.

Tourniquets.—Any apparatus by means of which graduated pressure can be made upon a vessel is a tourniquet. The original idea, as the name indicates, involved a twisting or screwing contrivance for graduating the pressure, which is the power employed in the instrument best known at the present day, the tourniquet of Jean Louis Petit (1674-1760). This instrument (Figure 51) consists of two metal plates, the distance between which can be regulated by means of a screw, and

which are connected by a strong silk or linen strap, which is meant to pass around the limb, and which is fastened by a buckle. In using this instrument the lower plate, underneath which a pad or a roll of bandage has been placed, should be applied exactly over the point corresponding to the artery (Figure 52); the strap that encircles the limb should then be drawn quite tight, when the screw is turned so as to force the pad

FIG. 50.—Compressing the femoral artery (*Esmarch*).

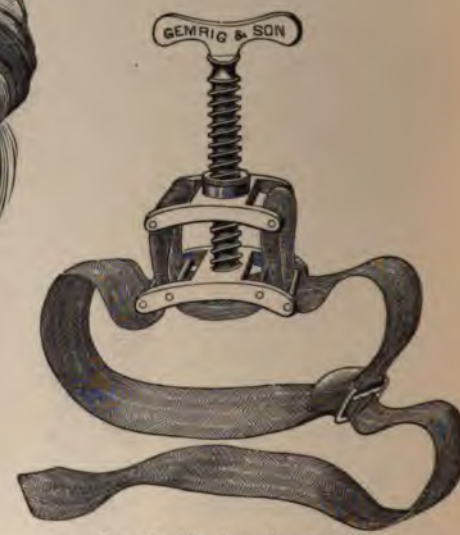


FIG. 51.—The tourniquet of Petit.

down upon the subjacent vessel until it ceases to pulsate. The tourniquet in use before the invention of the instrument of Petit was a simple band encircling the limb tightly, underneath which a stick was thrust, by the twisting of which powerful compression could be produced. The same method is still often adopted with advantage for improvising a tourniquet in cases of emergency. It is frequently spoken of as the "Spanish windlass." A handkerchief or bandage, or any similar material, to encircle the limb, and a stick, or rod of any kind, to twist it with, being the only essential things for its construction; a knot in the handkerchief or a stone enfolded may serve as a compress to apply directly

over the vessel to be compressed (Figure 53). Another form of improvised tourniquet, applicable to the brachial artery, is shown in Figure 54, in which by means of two sticks, arranged as shown in the figure, powerful pressure by leverage can be exercised on the vessel.

The application of a tourniquet should be discontinued at the earliest possible moment, on account of the pain which it produces, and the interference with the venous circulation of the parts beyond, as the result of which death of more or less of the limb may ensue. It is to be regarded

FIG. 52.—Compression of the femoral artery by tourniquet (*Agnew*).

FIG. 53.—Improvised torsion tourniquet (*Esmarch*).

only as a temporary expedient, to be substituted at the earliest practicable moment by other means of direct and permanent hæmostasis.

The Elastic Bandage.—If a piece of india-rubber tubing or bandage be wound with strong traction several times round a limb, and the ends be fastened by a knot or clasp, all the soft parts, and with them the vessels, are so firmly compressed that not a drop of blood can pass through. The facility and certainty with which the blood-current can be interrupted by such an elastic band has caused it to replace, to a very great extent, all forms of tourniquets, since attention was drawn to its advantages in connection with the bloodless method of performing surgi-

cal operations devised by Esmarch, of Kiel.[1] If an elastic bandage be put (no matter how tightly) only once round a limb, the pressure will not suffice completely to compress the blood-vessels; but if it be bound several times round at the same point, every turn so increases the pressure that in a short time no more blood can pass.

Acupressure.—Those methods of acupressure may be used to so compress a vessel in its continuity, so as to interrupt the flow of blood through it, in which, when the tissues are transfixed by the needle they are so put upon the stretch that by their elasticity they press the needle firmly and continuously against the vessel, or in which the needle, having been thrust under the vessel, is made the base against which pressure is made by thread thrown over the included tissues and about the projecting ends of the needle as in the harelip suture. Acupressure may thus be substituted with advantage in some cases for ligation of vessels in their continuity.

FIG. 54.—Double stick tourniquet (*Esmarch*).

Ligation.—When direct ligation of a vessel is impracticable on account of the depth or inaccessibility of the wound, or because the necessary disturbance of the wound, or perhaps its extensive enlargement to expose the bleeding vessel, is deemed inexpedient, ligation of the vessel

[1] *Ueber Künstliche Blutleere bei Operationen.* Volkmann's *Sammlung klinische Vorträge*, No. 58.

in its continuity above the wound, or of its parent trunk, will control the hæmorrhage definitively. Whenever permanent interruption of the main supply current to a part is necessary, ligation is to be performed. In the choice of material for the ligature, the same reasons exist for preferring the aseptic catgut cord which have been stated in connection with ligation in the wound.

Cardiac Sedatives.—Little is to be expected from the action of remedies administered internally for the immediate staunching of surgical hæmorrhage, but in the after-treatment they may play a more important rôle, combined with other general means. Gross[1] makes the following observations on the use of such means:

"Whatever mode of procedure be adopted for arresting the bleeding, it is an object of primary importance to place the affected part perfectly at rest, in an easy and elevated position; the slightest motion might be injurious, especially when no ligature has been used, and should, therefore, be sedulously guarded against. Repose of the body is equally necessary with that of the part, and it is hardly needful to add that mental tranquillity is also of the greatest moment. Cardiac action, too, must be maintained in the most perfect quietude, as any perturbing agency of this kind cannot fail to favor a return of the hæmorrhage and exhaust the system. With this view a full anodyne should be administered early in the disease, the dose being repeated from time to time so as to sustain the soothing influence of the remedy. Too much stress cannot be laid upon the use of opiates in the management of arterial hæmorrhage, and it is surprising that the remedy is not more generally employed than it seems to be. To allow the heart to go riot, or to move and toss about tumultuously, as it is so liable to do after serious loss of blood, while every local precaution is taken for the suppression of the bleeding, is assuredly a strange inconsistency, and one altogether irreconcilable with experience and common sense. When the bleeding proceeds from a great number of small vessels, a restraining influence may be expected from the administration of ergot in full and repeated doses.

"When high constitutional excitement exists, the effect of the anodyne should be aided by the judicious use of aconite or veratrum viride. When

[1] System of Surgery, 1882, vol. i., p. 675.

the skin is very hot and dry, a full dose of Dover's powder often answers an excellent purpose in calming the heart's action.

"The diet should be perfectly bland, and sufficient in quantity to supply the wants of the body. To give less might cause irritability of the system; to give more, over-stimulation. The drink must be cold and acidulated, and not taken so freely as to oppress the stomach, as it will be sure to do if the quantity is not carefully restricted, as the thirst is always urgent after the loss even of a comparatively small amount of blood. Lumps of ice, or pounded ice, held in the mouth, and gradually swallowed, often prove most grateful and beneficial. The air of the apartment must be kept perfectly cool; in short, every effort must be made to maintain the tranquillity of the circulation."

CHAPTER VIII.

THE GENERAL CONDITION OF THE PATIENT.

***Shock*—*Anæmia*—Auto-transfusion—Transfusion—Saline Infusions; Intravenous; Hypodermatic—Technique of Hypodermoclysis—Technique of Intravenous Infusion—Formula for Normal Salt Solution.**

SHOCK.

THE lighter degrees of shock quickly and spontaneously disappear. Very quick and complete recovery from a state of most profound shock may occur. The chief elements upon which recovery from shock depend are these: First, whether the injury has to do with a vital part; and, second, whether it entails a continued source of irritation and depression. Thus, in injuries to the head, the immediate shock may be overwhelming in consequence of the vital relations of the injured part, or when not at once fatal may be continued and masked by inflammatory conditions arising in the cerebral tissues as a consequence of the injury. So in crushing injuries of the extremities, the immediate shock of the injury may be prolonged and intensified by the pain and irritation arising in the mangled tissues, so that the surgeon may be called upon, even in the presence of much general shock, to run the risks of subjecting his patient to the additional brief shock of an amputation rather than leave him exposed to the continued irritation of his mangled limb, with possible added septic infection, while waiting for reaction to be established. In general it may be said that when an injury is not primarily fatal through shock, and continually renewed shock can be prevented, speedy recovery from the shock may be confidently looked for under proper treatment. Severe shock is so often complicated with the acute anæmia caused by loss of blood that it is difficult to separate its prognosis and treatment from those of the latter condition; nor in practice is it essential to do so.

The indications for treatment in severe shock include stimulation, free access of air, recumbent posture, warmth, and reassuring words if consciousness is present.

If the patient is able to swallow, brandy or other alcoholic stimulants should be given in small and frequently repeated doses till reaction is assured; if unconscious, these should be injected *per rectum;* if the prostration is extreme, hypodermatic injections of brandy, in doses of from one-half to one drachm every ten minutes till the patient is able to swallow. The flagging heart may be stimulated by the hypodermatic injection of strychnia, 1-20th grain, followed in half an hour by half that amount. Nitro-glycerine, in doses of 1-50th grain every half hour until three doses have been given, tends to dilate the peripheral arterioles and lessen the labor of the heart.

Heat and friction to the extremities, hot cloths over the heart and stomach, warm blankets to envelop the body, are also to be employed.

Copious hot enemata, a pint or more of simple saline solution, or an infusion of coffee, constitute a valuable resource. Of all measures the most positive and speedy in its effects is an intravenous infusion of hot (100° to 112° F.) saline solution of from one to three pints in amount. This is especially indicated when there has been much loss of blood, but even in cases not thus complicated its beneficial effects are marked.

If the respiration fails, artificial respiration is to be practised.

If the shock is being aggravated or prolonged by the irritation of a mangled limb, or the presence among the tissues of a foreign body, or the continuance of hæmorrhage, immediate operative interference is needed as the less of two evils; in all other cases operations should be deferred until reaction is secured.

As reaction comes on, stimulants are to be replaced by supporting and anodyne measures. Renewed evidences of prostration are again to be met by the use of stimulants.

ANÆMIA.

Should loss of blood have been so great as to cause the want of the blood to be a source of immediate danger, auto-transfusion should first be performed.

AUTO-TRANSFUSION is done when the blood is forced from the extremities and collected in larger quantities in the vessels of the central organs. For its performance, after the hæmorrhage has been stopped, the patient must be placed with his feet higher than his head, in order that the blood

may gravitate toward the heart and medulla oblongata; the limbs are then to be bandaged firmly, beginning at their distal portions, preferably with rubber bandages—in default of which, however, ordinary ones may be used—so that the limbs are rendered comparatively bloodless. If the fainting is extreme, complete inversion of the body, holding him up by both feet, is the most efficient method of revivifying the exsanguinated brain, while rhythmical compression of the thorax—artificial respiration—is the best means of stimulating the action of the heart and lungs.

TRANSFUSION.—When the loss of blood has been extreme, and autotransfusion has been inadequate to insure permanent rallying, the injection of a quantity of blood from a healthy person into the veins of the sufferer has been practised. One great advantage of the practice of autotransfusion was as a temporary expedient to gain time for the necessary preparations to be made for such transfusion. Although transfusion was practised only as a *dernier ressort* in desperate conditions, the results attained by it which are recorded were encouraging. When the operation had been performed for injuries to blood-vessels or for the hæmorrhage resulting from them, the recoveries were fifty-eight per cent.; when performed in consequence of *post-partum* hæmorrhage, the recoveries were fifty-six per cent.[1]

The operation is simple, easy to perform, and with careful attention to certain details, is free from danger. To prevent embarrassment from coagulation of the blood, its preliminary defibrination was advocated and received favor after it was shown that blood deprived of its fibrine and exposed to the air for some time was not materially deteriorated for restorative purposes. Rigors and febrile reaction, with a varying degree of general discomfort and sense of oppression generally occurred as sequelæ to transfusion, and were explained by the dissolution of the blood corpuscles and the liberation of fibrine ferment, the symptoms being those of "ferment intoxication." Consideration of the phenomena which attended cases of transfusion suggested that the benefit which followed its employment was due simply to the filling of the blood-vessels with sufficient fluid to restore the required tension to the vascular system, and not

[1] Howe: Transfusion of Blood. Annals of the Anatomical and Surgical Society, 1880, vol. ii., p. 164.

to the character of the particular fluid. The substitution of a simple saline solution, of the same specific gravity as blood serum, for injecting into the blood-vessels, was found to produce the same beneficial effects as had blood transfusion, and to be free from the dangers of ferment intoxication. It has followed, therefore, that the use of blood transfusion has been wholly abandoned, and saline infusion substituted.

Saline Infusion: intravenous; hypodermatic.—The most quickly acting and reliable heart stimulant when the vessels have been depleted by hæmorrhage is an intravenous infusion of hot normal saline solution. As the right heart feels the pressure of the infused fluid, the heart beats become lengthened and more forcible, and the blood pressure in the peripheral vessels rises. The filling of the blood-vessels by the fluid thus infused is, however, quickly lessened by its escape into the lymph spaces of the tissues, which had been earlier depleted by the absorption of serum taken into the capillaries as the vascular pressure was lowered by the primary hæmorrhage. As the bulk of a salt solution is soon taken up by the tissues, the blood pressure is lowered, the volume of fluid with which the heart has to work is again reduced, and the symptoms of acute anæmia recur. Hence the fact noted by many observers that the benefits of an infusion, though immediate and marked, are evanescent. If, however, by a second infusion the vessels are filled again, the tissues, being already supplied with fluid, do not absorb it from them, and a more permanent restoration of the vascular equilibrium is secured. To insure permanence, therefore, in the cardiac and vascular reaction produced by an infusion, the amount of fluid infused should be large, from one to two quarts, or a repetition of the infusion, using a smaller quantity, twenty to forty fluid ounces, should be practised, the second infusion being made as the effects of the first one are found to be waning. Copious enemata of salt solution may serve to supply the needed extra amount of fluid to the body and render unnecessary a second infusion. It is recommended that in all cases in which an infusion is made a quart or more of the salt solution should also be thrown into the colon through a long tube. The routine employment of such copious high enemata after all serious or prolonged operations diminishes much the depression attending such operations and lessens the gastric irritability and the thirst commonly following them.

In cases of acute anæmia of less emergency, or in the absence of facilities for the proper performance of intravenous infusion, the saline solution may be injected into the subdermal connective tissue spaces (hypodermoclysis). The injecting needle, attached by suitable tubing to a

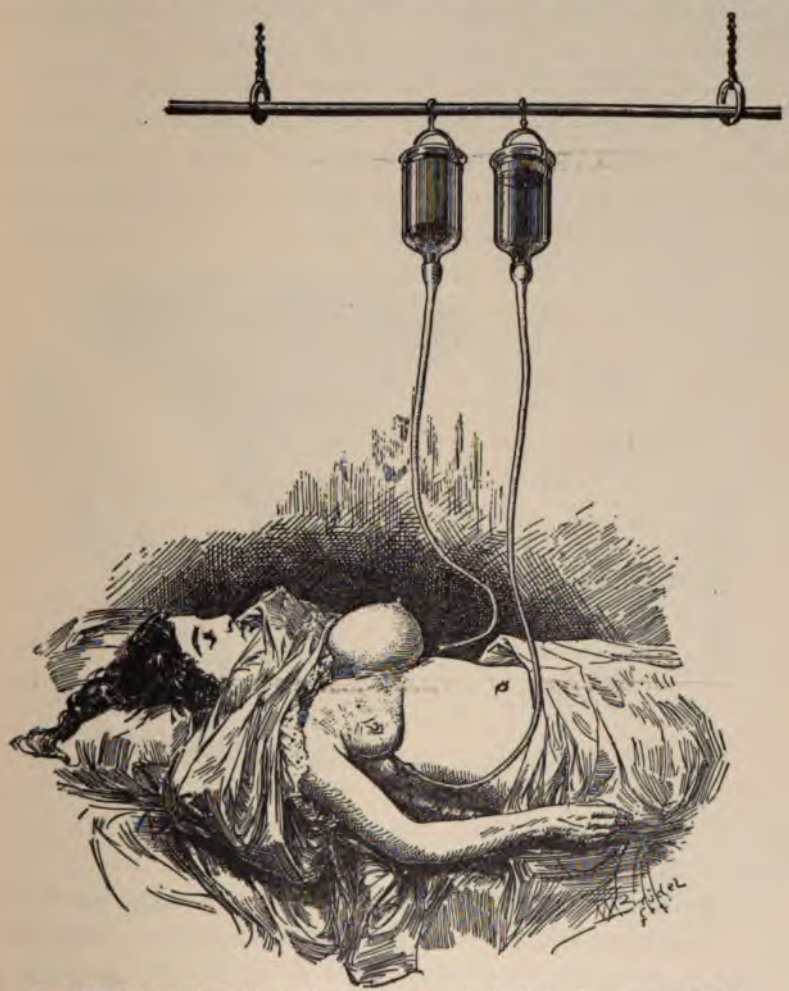


FIG. 55.—Introducing salt solution under breasts by hydrostatic pressure (*Kelly*).

sterile syringe or gravity apparatus, may be thrust into the loose tissue under each breast, where from twenty to thirty ounces of fluid can be readily accommodated (Figure 55).

The following is the technique of hypodermoclysis as described by

Kelly: "Two suitable bottles are filled each with 1,000 cubic centimetres of normal salt solution at a temperature of 100° F. A rubber tube six feet long, to which is attached a long, slender, sharp aspirating needle, completes the apparatus. The skin of the breast is carefully disinfected; the breast is then grasped and lifted well up from the chest, while the needle with the salt solution flowing is thrust into the cellular tissue well under the glandular substance. The bottle is elevated six feet above the patient in order to give sufficient hydrostatic pressure to force the fluid into the tissues. As a rule it requires about twenty minutes to infuse from 700 to 1,000 cubic centimetres of the solution under both breasts. As the infusion proceeds the gland becomes greatly distended. At the comple-

FIG. 56.—Collin's instrument for transfusion.

tion of the operation a piece of adhesive plaster must be placed over the point of puncture to prevent leakage."

The wash-bottle injecting apparatus (Figure 58) recommended for use in intravenous infusion is equally serviceable for hypodermoclysis, by substituting a sharp-pointed aspirator needle for the blunt canula that is attached to the delivery tube.

The transfusion instrument of Collin (Figure 56) is very convenient for hypodermoclysis.

In this instrument the funnel acts as a reservoir, into which is poured the salt solution, which is drawn from it by the syringe, and driven thence

through the tube and canula into the recipient connective tissue spaces. The opening to the tube is guarded by a ball-valve, which permits only fluid to enter. The entrance of air is thus guarded against. The air originally in the tube should be first expelled by forcing some of the fluid through it, immediately before inserting the canula under the skin.

Technique of Intravenous Infusion.—When intravenous infusion is to be performed, a vein is uncovered at the bend of the arm, or above the inner ankle, by a free incision through the overlying skin. When the vein has been clearly exposed, its anterior wall is to be seized by a toothed forceps and lifted up, while a transverse incision is made with knife or scissors in the vein, extending through about two-thirds of its wall, so as to make a valvular opening (Figure 57). While the flap that has been made is still held up by the forceps, the canula is to be introduced. Judgment is necessary in the selection of a canula, that too large a one be not chosen. As a rule, difficulty will be experienced in introducing into the veins mentioned a canula of greater diameter than three or three and a half millimetres. A catgut ligature previously passed under the vein above the point of opening is now tied so as to secure the canula in place; a similar ligature below the vein-wound is also tied.

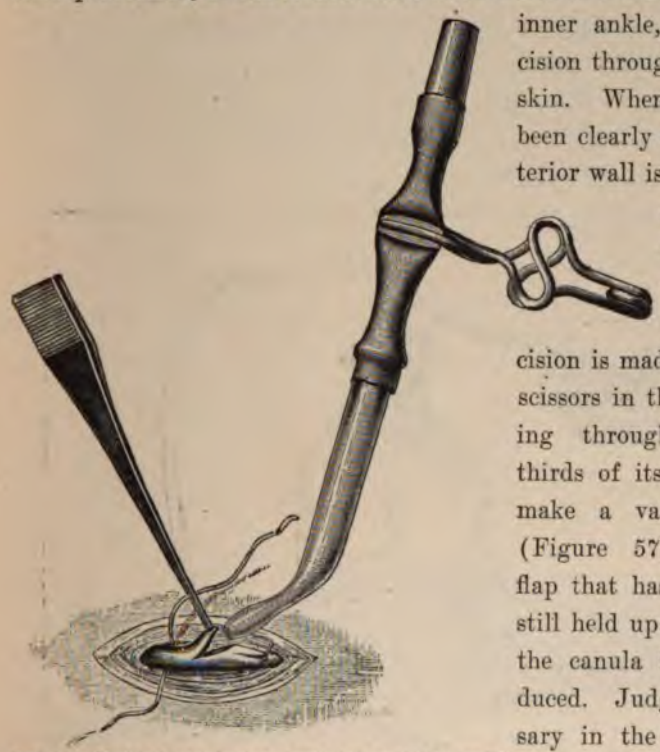


FIG. 57.—Mode of introducing canula into vein (*Esmarch*)

The fluid for infusion in cases of emergency may consist simply of boiled water and common salt in the proportion of six parts of the salt to the thousand of water. A more accurate imitation of blood serum,

termed *normal salt solution,* contains all the salts of blood serum in their proper proportions. The formula for the preparation of this solution is as follows:

R. Sodii chloridi.....℥ iv, gr. vi;
Sodii sulphatis..... gr. xi;
Sodii carbonatis.....gr. Vss;
Sodii phosphatis.....gr. iii¾;
Calcii phosphatis..... gr. ix⅛
Magnesiæ phosphatis.....gr. ix⅛. Ux.

Sig. Make into one powder and dissolve in six quarts and nine ounces of water.

Fig. 58.—"Wash-bottle" injecting apparatus for intravenous infusion of saline solution.

Such powders should form a part of the stock armament of a surgeon, ready for solution as needed.

For the regular, slow and continuous infusion of the fluid into the

vein the ordinary apparatus for fine injections used in the biological laboratories is unequalled, and may readily be extemporized wherever a large bottle, a cork, some glass and rubber tubing, and the bulb of an atomizer can be obtained. This is also practically the wash-bottle of the chemist. It is shown in Figure 58.

The bottle containing the solution should be placed in a large pan filled with water heated to the temperature desired for the infusing fluid (112° F), whereby the cooling of the fluid in the bottle may be prevented.

of the reservoir, and be made into a syphon, it will answer just as good a purpose. By elevating and lowering the reservoir, the force of the stream can be perfectly graduated, according to the will and judgment of the surgeon; by replenishing the supply of fluid in the reservoir, as needed, the time through which the irrigation shall be continued may be indefinitely prolonged.

In the after-progress of the wound, if union by first intention be not secured, recourse to irrigation for the purpose of cleansing it of retained secretions, and of sloughing *débris,* may be necessary. In this respect it largely supplements drainage, and the measure of its frequency and importance is the measure of the imperfection of the provisions for drainage. The aim should be, in all cases, first, by irrigation to remove all foreign, or dead, or waste products from a wound; and second, by drainage to prevent their reaccumulation. Whenever adequate drainage has been impracticable, continuous irrigation might become of value in preventing accumulation of noxious substances. The temperature of the water used for irrigation should always be equal to that of the blood, for a lower temperature exerts a depressing influence on the reparative energy of the wound.

Continuous submersion in warm and hot water is a form of irrigation, and its favorable effect, when experienced, is due to the cleansing of the wound which it accomplishes, as well as to its influence in promoting resolution of inflammatory complications. The value of such continuous submersion in an antiseptic fluid in the treatment especially of lacerated and contused wounds of the extremities is very great. The favorable effect of submersion upon the progress of a wound will not be obtained when the character of the wound is such that all its recesses are not freely accessible to the water, and when the escape of the wound-discharges is impeded. In addition to the diluting and cleansing function of the continuous irrigation that is accomplished, the favorable results obtained are due also to the favorable effect upon the nutrition of the immersed part which the warmth and protection of the hot-water bath afford.

Irrigating Fluids.—Since ordinary water is a common vehicle for bacteria, that which is to be used for irrigating wounds must be sterilized by boiling or by adding to it some antiseptic in sufficient strength to destroy any bacterial life that may chance to be in it. The normal salt so-

lution, sterilized, is to be preferred to pure water for general irrigating purposes, as absolutely free from irritative effects upon the tissues. The antiseptic solutions are to be used only in the presence of recognized infection, since they are themselves sources of irritation and of tissue necrosis. Of the various antiseptics those that will be found most generally available and reliable for this purpose are corrosive sublimate in the proportion of 1 part to 2,500 of water; the boro-salicylic solution (one ounce of boracic acid and eighty grains of salicylic acid in one gallon of water); permanganate of potash, 1 to 100; carbolic acid, 1 to 40, and tincture of iodine, 1 to 40.

DRAINAGE.

Cleansing of the wound is finally completed by providing means to prevent the recurrence in the wound of conditions of wound-contamination. Of these, the first, and most important, is the establishment of a free, short, and direct channel, through which the wound-secretions may freely and continuously flow away. The application of the term "drainage" to this portion of the management of a wound is happily appropriate, for the same physical problem is present for solution as that encountered by the farmer who desires to rid his land of undue and hurtful moisture. His ditches, canals, and drains find their counterpart in the devices adopted by the surgeon to rid wound-cavities of accumulating secretions.

The provisions for drainage may be divided into *natural* and *artificial*. By natural being meant whatever arrangement or dressing of the wound shall favor the escape of secretions, apart from the insertion of any apparatus as means of conduction; by artificial being meant such tubes, setons, or tents, as may be necessary to supplement or replace natural means.

Natural Drainage may be secured in many instances. In wounds in which good coaptation of the surfaces has been possible, and yet in which reasons exist for expecting the production of much secretion, the escape of such secretion may often be sufficiently provided for by leaving open the most dependent portion of the wound. In other wounds in which secretions have accumulated so as to produce tension, by cutting one or more sutures sufficient gaping of the wound may be permitted to answer

the needs of drainage. In yet others, the cutting of all stitches, and the unrestricted separation of the entire wound-borders may be deemed best. The "open" method of treating wounds, which has been proven to possess great merits in many instances, is a method in which thorough natural drainage is provided for, and to this unquestionably a large share of the benefits derived from the method are due. The results of different forms of the "open" treatment show that the chief thing of importance in its management is that free escape of secretions be not prevented. For the purpose of securing this free escape wounds are to be enlarged by free incisions, and counter-openings made whenever required. Natural drainage may be resorted to for the removal of the bloody and serous oozing that occurs during the first twelve to twenty-four hours after the occurrence of a wound, by leaving the wound open during that period, septic infection being prevented by the use of sterile iodoform dressings; when the farther secretion has in great measure been arrested, the surfaces are brought together and sutured, without any necessity for further drainage.

ARTIFICIAL DRAINAGE includes all methods in which foreign substances are introduced into a wound for the purpose of conducting away its discharges. These substances may act by capillarity, serving to keep the wound-surfaces apart, and permitting the outflow of liquid to take place along the interstices between their strands, or may provide tubes through which a free flow is secured. The use of various artificial means for drainage is among the ancient resources of surgery. Guy de Chauliac (1300-1370) taught that it was necessary to place tents and setons "in wounds which you would enlarge, cleanse, or from the bottom of which you would withdraw anything, as in deep wounds which have need of counter-openings, because of the liquor or the liquid excretion which gathers at the bottom and in its recesses." One can also make use, he says, "of a tube of brass or of beaten silver that the ordure may escape from it and not be retained."

But not until within the last half of the present century has the full importance of artificial means of drainage been demonstrated and its practice been systematized. With the systematic practice of drainage the name of Chassaignac is associated, whose researches were published, in 1859, in a work entitled, *Traité pratique de la suppuration et du drainage*. His method consisted in traversing from top to bottom all purulent

collections with vulcanized rubber tubes pierced with holes along their sides. He demonstrated and fixed in surgical practice the importance of preventing the retention of pus, and introduced a perfect method of drainage for purulent secretions.

TUBULAR DRAINAGE.—Pus cannot be satisfactorily removed by capillary drains; its thickness and tenacity prevent its escape through such channels; a tube of some kind or other must be used to secure its escape. The india-rubber tubes introduced by Chassaignac, being flexible, unirritating, easy to manipulate, nearly always attainable, and cheap, continue to be regarded as the most universally applicable means of drainage for pus. These tubes may be obtained of varying diameters, from one-eighth of an inch upward, and of any length. The original tubes of Chassaignac were made of black rubber, which has been considered objectionable from the liability of the free sulphur contained in them to generate sulphureted hydrogen, and thus to produce disagreeable smells. This objection has been obviated by substituting red rubber for the black rubber in making the tubes. When they are to be used for drainage purposes lateral openings should be made in them at short intervals, the diameter of each hole being about one-third of the circumference of the tube. These openings can be readily made as needed, by simply bending the tube sharply on itself and snipping off one of the projecting corners at the bend with a pair of scissors. (See Figure 59.)

Tubes of metal, as silver, aluminium, or tin, and tubes of glass may be substituted for the rubber tubes, when the compressible and flexible nature of the latter is liable to be the occasion of their obstruction by their becoming bent, or from the pressure of the tissues through which they pass, or of the dressings that may be applied.

In wounds in which the amount of secretion for the escape of which provision is to be made is not very great, a simple bit of folded rubber tissue may be inserted at a suitable point between the lips of the wound. This prevents the adhesion of the wound margins and provides a line of least resistance along which the secretions from the deeper parts may flow to the surface.

A drainage tube, of whatever substance composed, is a foreign body, and as long as it remains in a wound is liable to provoke disturbance. They should therefore be removed as soon as the period of profuse secre-

tion, which has made their original use necessary, has passed away, or as soon as the cavity which they were intended to drain has become obliterated. In incised wounds no drain should be used when the two surfaces can be brought accurately together and maintained in apposition. It is only when care in adjustment, and the use of proper means for retention and support and compression prove to be insufficient to secure and maintain accurate adjustment of wound-surfaces that the use of a drain is indicated.

The necessity for the removal of a drain, or its readjustment, if its continued use is indicated, may be a source of disturbance to the progress of the wound, and, in any event, as long as it remains in the wound, more frequent dressing of the wound, with its attendant dangers and disadvantages, is necessitated.

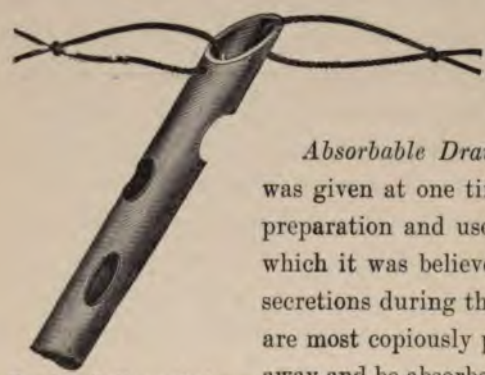


FIG. 59.—Ordinary drainage tube.

Absorbable Drainage Tubes.—Much attention was given at one time (Macewen, Neuber) to the preparation and use of drains of decalcified bone, which it was believed would secure free escape to secretions during the first days, during which they are most copiously produced, and then would melt away and be absorbed spontaneously without necessitating any exposure of the wound or change of dressing for their removal; but practical difficulties were found by experience to often prevent the realization of the ideal advantage expected to be derived from these bone drains. They were prone to suffer untimely collapse, and cease to act as drains from lack of sufficient hardness of their walls when immersed in the wound-secretions. The expedient of forestalling this accident by stuffing them with horse-hair to keep them patent was simply the substitution of a non-absorbable drain, and defeated the special object—infrequency of dressing—which the bone drains were devised to answer. Again, when not too soft, they might yet become absorbed before the necessity for drainage was over, and by their disappearance determine retention of secretions. This particularly was liable to occur in wounds which had not been preserved aseptic, and those in which the discharge was profuse—

conditions in which, especially, perfect freedom of drainage is important. Lastly, if the drain should happen to become surrounded by a coagulum or by devitalized tissue its absorption would be indefinitely delayed. These uncertainties in the behavior of bone drains have prevented their use from becoming general.

CAPILLARY DRAINAGE.—The thin bloody serum, which constitutes the primary secretion poured out from a wound, is capable of conduction to the surface by agents that exert upon it a capillary attraction. For such a purpose those agents only are to be used which are sterile, unirritating, and sufficiently fine in texture that the interspaces formed when they are made into bundles shall be minute enough to exert well-marked capillary attraction.

Sterile gauze made into suitable rolls or folds, or absorbent cotton wicking, is the material chiefly depended on for capillary drainage. Strands of catgut, horse-hair, silk-worm-gut and of spun-glass have been at various times recommended as of value for capillary drains, but for general use are less convenient and no more efficient than the gauze fold. A slight amount of iodoform in the gauze does not interfere with its efficiency as a drain, and diminishes the probability of serious bacterial infection while the drain is in place. A large receiving mass of absorbent gauze, or other absorbent material, should be placed upon the outside of the wound, enveloping the outer end of the drain, and this external dressing should be changed whenever it has become saturated with the discharge. The chief draining power of such a capillary drain is during the first twenty-four hours of its use; its meshes soon become more or less filled with lymph and its surfaces become adherent to the wound-surfaces with which they are in contact. If an attempt be made to withdraw a gauze drain at the end of twenty-four or forty-eight hours, it will be found to be so adherent that considerable force will be required to get it out, and the rupture of the adhesions will cause considerable pain and provoke some bleeding. After forty-eight hours more—that is, by the fourth day—the excessive amount of lymph thrown out around the drain as a foreign body will have caused the liquefaction of the earlier adhesions, loosening the drain and permitting its withdrawal with ease, painlessly and without hæmorrhage. A gauze drain, therefore, unless important reasons for its early removal appear, such as profuse hæmor-

rhage or the retention of septic secretions behind it, should be left undisturbed until the fourth day after being placed. In most cases when the drain is removed, no further need for drainage will exist, and the drain-track, left to itself, quickly contracts, its walls adhere, and it becomes obliterated. Should suppuration declare itself in the depths of the wound, a tube drain should be substituted.

To prevent adhesion of the wound-surfaces to a gauze drain, it has been recommended to envelop the greater part of the gauze in gutta-percha tissue or oiled silk, leaving exposed only the ends. This is effective for the purpose intended, but it prevents the absorption of secretions from the surfaces lined by the impermeable tissue, and facilitates the entrance into the deeper parts of the wound of the secretions from the more superficial parts, the full disinfection of which is always uncertain, so that the practice is objectionable.

General Considerations as to Artificial Drains.—Drains, of whatever character, should be so placed as to carry the secretions from the deeper parts of the wound, as well as from any irregularity or recess, by the straightest and shortest road practicable to the surface. To secure this it will often be good practice to make a counter-opening through which the drain may be carried rather than bring it out through the wound proper. Several short drains, rather than one long one, is usually to be preferred. They are of the greatest importance during the first forty-eight hours, and in deep, extensive, and irregular wounds. The first dressing is often soaked with bloody serum in twenty-four hours, or even much earlier. When it is necessary to employ drainage tubes for a considerable time they require periodical shortening. The tube should be large in size, rather than small, placed where it cannot be compressed, and have no elbows. Two tubes, side by side, often work very well. The time for their removal depends on the amount of secretion. After four to six days the channel in which the drain lies becomes lined with plastic matter, and will remain open for a short time after its removal; where several drains are present they ought to be taken out, one after the other, after an interval. The ends may be cut transversely or obliquely, so that they may always terminate flush with the surface, and never project beyond it; any projecting part is pressed on by the dressings, and the other extremity will thus be forced upon and irritate the wound-surface, and

the function of the tube is impeded. A sterilized safety-pin should be inserted at the outer end, for the purpose of preventing the tube from slipping into the wound-cavity, or the outer end may be secured in place by a point of suture passed through it, fastening it to the adjacent margin of the skin wound.

Resume.—The two indications to be accomplished by drainage of a wound—to prevent the accumulation of ferment pabulum, and to remove fluids already the subject of ferment changes—mean practically the drainage of serum and the drainage of pus. The first is primary and preventive in its nature, the latter secondary and corrective.

Primary Drainage.—Since the retention of accumulated serum within a wound not only acts as any foreign body to prevent apposition and to disturb healing mechanically, but also is prone to rapidly become a fountain of poison to the wound, as ferment changes take place within it, the problem of its removal becomes a question of primary importance in wound-treatment, and is second to no other involved in the subject of wound-cleanliness. The paramount importance of primary drainage was one of the most prominent points insisted upon by Mr. Lister, to whose teachings and practice its establishment in its proper place in wound-treatment is due in great measure. The use of drains, however, is to be regarded always as a complication, which, if possible, should be avoided, and to be adopted only when other possible means for limiting the amount of serous exudation and preventing its accumulation must be inefficient. When drains are unavoidable, they should be removed as soon as possible, that is, as soon as the tendency to serous exudation ceases, or the obliteration of the cavity drained by them is accomplished, a period of time varying usually from one to four days.

Secondary Drainage.—The drainage of purulent fluids constitutes what I have chosen to call secondary or corrective drainage. For this purpose capillary drains are inadequate, and tubes must be used if artificial drains are required. This is the form of drainage with which the name of Chassaignac will always be associated. In its use, the tube, of whatever material, must be removed from the wound at each dressing, and washed with a strong antiseptic lotion. If this be not done, portions of decomposing material will remain inside the wound, entangled in the openings of the tube, and will become more and more putrid and noxious.

The tubes likewise afford a means for irrigating suppurating cavities with cleansing and antiseptic lotions.

ACCESSORY MEANS OF WOUND-CLEANLINESS.

Second only to the means used for cleansing the wound-surfaces themselves are to be regarded those for cleansing the tissues adjacent to the wound, and for purifying all substances, such as the hands of the surgeon, instruments, retaining and protective dressings, and the air itself, which are brought in contact with the wound. These require consideration in this connection.

All that portion of the surrounding integument which is to be included with the wound under the protective dressings must be thoroughly disinfected. In the case of operative wounds, inflicted by the surgeon, this disinfection should be done before making the wound; in the case of accidental wounds, it should be done before applying the dressings. The skin should be shaven, and then thoroughly scrubbed with a flesh-brush and with soap and water, and then with ether, to remove fatty matters, and finally well washed with a penetrating antiseptic solution (carbolic acid, 1 to 20, or preferably corrosive sublimate, 1 to 1,000), the antiseptic solution being allowed to act for some time. Whenever the dressings are removed, the purification of the surrounding skin is to be repeated; and in the treatment of wounds in specially septic regions, as the axilla and perineo-scrotal regions, the dressings should be renewed with more frequency than in other regions, for the purpose of preventing auto-infection.

The hands of all persons employed about a wound should be thoroughly purified, in accordance with the directions which have been given in the chapter on THE PREVENTION OF INFECTION, page 95. All the details described there for securing disinfection of hands, of clothing, of instruments and appliances, and of dressings, should be complied with as far as the conditions attending the particular wound make it possible to do so.

The external dressings which are applied for the purpose of maintaining apposition in a wound, of exercising compression upon it, and of affording protection to it, must satisfy certain conditions of cleanliness, if

they are not to become agents of harm rather than good to the wounds to which they may be applied. While they must be soft and mechanically unirritating, and must be capable of absorbing whatever secretions emerge from the wound, and thus contribute to the efficacy of drainage, they must also themselves be free from noxious organisms. Many substances have been used which more or less perfectly satisfy these conditions. Cotton wool and loosely woven cotton cloth (book-muslin, tarletan, cheese-cloth, gauze), lint, paper, jute, moss, charcoal, sand, and sawdust are some of the agents which may be used for wound-dressings. But to fit them to completely answer the requirements of wound-cleanliness by acting as efficient protectives against the access of noxious organisms, it is necessary that they should each be sterilized, and in some cases should be charged with special antiseptic substances. See Chapters VI. and XI.

CLEANSING SEPTIC WOUNDS.

If a wound has been exposed for some time and has already become suppurating and inflamed, its immediate complete disinfection through any local antiseptic applications that can be made to it, however energetic and thorough they may be, is not to be expected. In such wounds it is to be remembered that it is not only the discharges and the superficial surfaces in which the septic germs exist and must be destroyed, but that these organisms have infiltrated to a varying extent the subjacent tissues. The chief effort of the surgeon should be to remove all retained secretions and devitalized tissue that could afford a medium for active bacterial development, or by their resultant decomposition could keep up or intensify the local tissue irritation; this having been done, the indications are to provide free drainage and to stimulate local cell activity. As a preliminary to any cleansing applications it is important that all wound-cavities and recesses be freely laid open, as far as possible. The mere conversion of a penetrating or sinuous wound-track into a free superficial wound is sufficient of itself to rapidly modify the intensity of its septicity and to encourage more healthy granulation in its cavity. Free exposure of the wound-recesses having been done, all blood-clot and disorganized tissue should be removed, with any wound-secretions that may have been retained. Should an unhealthy granulating surface be

exposed, as is the case in many chronically suppurating wounds, the soft granulation-material should be scraped away just as has long been the practice in dealing with carious bones, and as is most systematically and perfectly done by dentists in the treatment of carious teeth. For this

FIG. 60.—Volkmann's sharp spoon.

purpose spoon-shaped curettes, as those of Volkmann, Figure 60, or of von Bruns, Figure 61, are efficient. They scrape away all the soft inflammatory material, but are not sharp enough to materially attack the healthy soft parts beneath. In addition, when tissues are evidently infiltrated with septic matter, they should be cut away or scarified deeply to admit of the escape of the ptomaine-laden serum with which they are infiltrated, and to favor the more perfect penetration of antiseptic solutions.

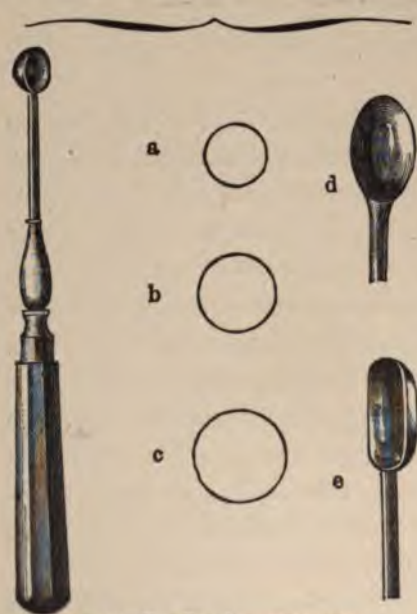


FIG. 61.—Von Brun's spoon curettes.

In all irregular wounds, and in those opening into cavities, in which it is not practicable to freely lay the entire track of the wound open, counter-openings should be made at suitable points to insure free through irrigation of all the recesses of the wound or cavity.

After this preliminary preparation the wound must be irrigated with a strong, bactericidal lotion. Every recess of the wound must be reached by the disinfecting fluid. The lotion must be used in sufficient quantity to thoroughly soak the tissues. Although the absolute disinfection of such a wound by the most thorough irrigation is always uncertain, still that a favorable modification of the intensity of the infection, and in some instances such diminution of bacterial activity and such

stimulation of local cell energy as to secure subsequent healing without further septic disturbance, may be secured, is a common experience. (See page 73.) In an open wound, under otherwise favorable circumstances, this may often be accomplished; but when septic changes have been going on for some time in irregular cavities, or in cases of septic phlegmon extending into the intermuscular spaces, in suppuration of the articulations, or in severe compound fractures, it is not to be expected.

Chloride of zinc is to be preferred as the germicide to disinfect septic wounds, because its caustic effect causes the disinfection produced by it to extend more deeply into the subjacent tissues, and because the protective film, which its combination with the albuminoids of the tissues produces, resists for so long a time the effects of any septic matters still remaining in other parts of the wound or introduced from without. The eight per cent. solution (forty grains to the ounce of water) should be used. It may be applied by irrigation, and, in addition, the wound-cavity should be filled with compresses soaked in the fluid.

Corrosive sublimate, 1:1000, may be preferred for injecting irregular cavities and narrow sinuses. In the after-cares more dilute solutions may be used. Throughout the future course of such a wound, greater care and watchfulness against the possible redevelopment of septicity will be required than would be deemed necessary in the management of a wound aseptic from the first.

CHAPTER X.

APPOSITION OF THE WOUND-SURFACES.

Position—*Bandaging*—Rollers—Compresses—Adhesive Plaster—Ichthyocolla Plaster—Gold-beater's Skin—Collodion—Application of Adhesive Bandage—Objections to Adhesive Bandages—*Suturing*—Needles—Needle-holders—*Thread*—Silk—Catgut—Chromicized Catgut—Silk-worm-gut—Horse-hair—Metal Wire—*Application of the Suture*—Stitches of Coaptation, of Approximation, of Relaxation—Knotting—Removing the Stitches—*Classification of Sutures*—Interrupted—Continuous—Pin—Quill—Bead—Button—Sutures *en étage*—The Crossed Suture—The Subcuticular Suture—Secondary Suture—Résumé.

THE apposition of the separated surfaces of a wound is to be accomplished by Position, Bandaging, and Suturing.

POSITION.

The advantage to be derived from position becomes apparent when attention is directed to the effect upon the spontaneous gaping of the wound of varying attitudes of the wounded part. A wound over the front of the knee gapes widely when the knee is bent, though it may show but slight tendency to open when the knee is extended. The edges of a transverse wound upon the anterior surface of the neck fall together when the head is inclined forward, while a similar wound on the back of the neck is made to gape by the same movement. Wounds dividing muscles transversely gape most widely when positions are assumed in which such muscles are put upon the stretch. The general rule, therefore, which is to be observed as to the position of a wounded part, in attempting to secure and maintain apposition of the wound-surfaces, is that the part should be placed in that position in which the greatest relaxation of the parts can be secured. In this position they should be fixed and held until firm union has been accomplished.

BANDAGING.

Bandages to approximate separated parts may be either roller bandages encircling the entire member, or bandages dressed with adhesive material—adhesive plaster—short strips of which, passing across the wound and adhering to the skin on either side, suffice to keep the parts apposed.

FIG. 62.—Double-headed roller.

A simple roller-bandage may be all that is required to perfectly approximate longitudinal wounds, and wounds in which there is little tendency to gape, or in which that tendency has been overcome by attention to position. By the use of the double-headed roller, as in Figure 62, or the invaginated bandage, as in Figure 63, the tissues may be made to slide toward each other from either side, and perfect apposition be secured in many cases. In all deep wounds the assistance of a bandage and of compresses is indispensable in maintaining apposition of the deeper parts of the wound. The compresses should be placed on either side of the wound, and upon it, in such position that the encircling bandage shall through them produce especial pressure of the deeper surfaces of the

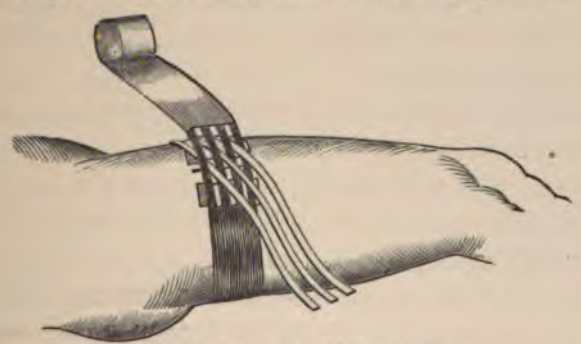


FIG. 63.—The invaginated bandage.

wound against each other. In the case of certain wounds, as of the face, neck, and trunk, in which the use of a roller bandage is impracticable, relaxation and compression of the wounded parts, so as to insure their continued apposition, is best accomplished by carrying broad strips of ad-

hesive plaster across the wound, so as to grasp the tissues for some distance on either side after these have been crowded up toward the wound by the hands of an assistant, so as to take off all tension in the wound itself. Underneath these strips and upon the wound compresses may be placed, of sufficient bulk to insure continued pressure of the wound-surfaces against each other. When a bandage is applied at any part of a limb so as to encircle it, its application must be preceded by careful bandaging of the distal portion of the limb, from the fingers or toes to the seat of injury, to prevent strangulation.

Rollers.—The material out of which the bandages shall be made should be soft, strong, and somewhat elastic, so as to adapt itself snugly to the parts to which it is applied. Cotton cloth—muslin sheeting—that has been repeatedly washed and freed from the stiffness of the new material, is usually available, and answers well the purposes of a bandage. Material that has been worn until it is tender should be rejected. The loosely woven cheese-cloth, or gauze, when attainable, is to be preferred, in some cases, to ordinary muslin. It is lighter, cooler, more elastic, and permits the passage of discharges more freely through it. Cloth of any kind should always be torn in the direction of its length in making it into bandage strips.

Compresses.—Purified gauze and cotton-wool are the best materials for use as compresses. They are unirritating, light, elastic, and absorbent. Masses of charpie, of oakum, or other similar substances may be likewise used with advantage.

Adhesive Plaster.—The ordinary adhesive plaster consists of muslin which has been smeared with a mixture of litharge, olive oil, resin, and soap. This mixture, while fluid by heat, is spread over the surface of the muslin, and upon cooling forms a thin coating, that becomes soft and adhesive when again exposed to heat. When it is to be applied, strips of suitable size and length are cut from the muslin roll thus prepared, observing the precaution to cut the strips lengthwise of the cloth, not transversely, lest they should stretch unduly after having been applied. The most convenient method of heating these strips for application is by pressing their unspread surface against a vessel, as a tin cup, a bottle, a tea-kettle, or the like, containing boiling water; they may also be heated, but less conveniently, by exposing them to an open fire, holding them over

the chimney of a lighted lamp, before a gas-light, etc. A form of adhesive plaster which does not require to be heated before it is applied was introduced to notice in 1877, by Dr. Henry A. Martin, of Boston, Mass., which has received much favor, and, under the name of "Rubber Plaster," has been since imitated by many makers. The adhesive coating of this plaster is composed of Para rubber, Burgundy pitch, and balsam of Tolu. It is flexible, water-proof, comparatively unirritating, and does not deteriorate with keeping, and it is to be applied at once without any preparation.

Ichthyocolla and skin plasters, and collodion may serve as substitutes for the ordinary adhesive plaster in the approximation of small and superficial wounds.

Ichthyocolla Plaster is made by applying to silk a solution of isinglass in alcohol. When it is to be applied, it has simply to be moistened by passing a damp sponge over its glazed surface. Its adhesive properties are weak, and it cannot be used where there is moisture, so that its use is restricted rather to the amateur dressings of the laity, to whom its greater elegance of appearance and the ease of its application commend it. What is called *court plaster* is a variety of isinglass plaster.

Gold-beater's Skin.—A delicate membranous film, made from the intestine of the sheep or the peritoneum of the bullock, when applied to a moistened surface adheres with sufficient firmness to withstand considerable traction. It is applicable particularly to slight wounds of the eyelids, or as a protective layer over an excoriated surface.

Collodion.—A solution of freshly prepared gun-cotton in ether, assisted by a little alcohol, when applied to a dry surface, by the rapid evaporation of the ether, leaves a transparent film that adheres strongly and contracts considerably. It may thus be used for fastening strips of silk or muslin to the edges of a wound, in place of other adhesive material, or may be applied directly over the wound as the only dressing, or as supplementary to other agents in sealing up the wound. It is most useful as a final application to wounds that have healed, upon the withdrawal of other dressings, applied over the cicatrix which it protects, giving it a needed support in resisting the inevitable tendency to reopening of the wound, which may be more than the fresh and tender new uniting material can withstand.

The Application of the Adhesive Bandage.—The skin to which a strip

of adhesive plaster is to be applied should be shaven, well washed with soap and water, and carefully dried, to present a surface to which the plaster can adhere, and to save the patient from the pain that would be caused by their removal if the hair was adherent to the plaster. One end of the strip is then to be pressed upon the skin upon one side of the wound, and while the edges of the wound are held together by the surgeon, the strip is carried across and fastened upon the other side. Care is to be exercised that inversion of the edges of the wound be not occasioned, and equal care that sufficiently firm approximation is secured to prevent their after separation. The first strip should be placed across the middle of the wound, and an interval of from one-quarter to one-half an inch left between each succeeding one, to admit of the escape through the intervals of wound secretions. As soon as strips thus applied lose their hold, become sources of irritation or obstruct drainage, they should be removed. But unless some such indication exists meddling with them is objectionable, as it tends to do injury to the healing of the wound. The cleansing of the wound is to be limited to gently wiping from the surface of the wound and of the dressings whatever secretions may have gathered there. When the removal of the plasters is necessary, gentleness of manipulation must be observed; the two ends of each strip should be lifted first, and the central part last detached from the line of the wound itself, lest by dragging the strips from one side to the other the wound be reopened.

Objections to Adhesive Bandages.—The use of adhesive bandages for the purpose of producing direct apposition of wound-surfaces is objectionable from its interference with wound cleanliness. The muslin strips may themselves be carriers of infection, unless they are disinfected with equal care with everything else that is allowed to come in contact with the wound. They may favor infection again by sealing up that portion of skin upon which they are laid from the action of the antiseptic dressings that may be applied over them, and thus fostering the creation underneath them of foci of sepsis from the development of organisms hidden in the depressions and follicles of the skin that will have escaped the primary disinfection of the part, however thoroughly done. Still farther, extending as they must some distance in every direction from the wound, as soon as they become wetted with the wound-discharges, they become favorable media for the propagation from the periphery of the dressings

inward to the wound of micro-organisms from without. In addition to these objections, which are of vital importance in efforts at preserving asepticity in wounds, they are also chargeable with being unreliable in the support they may give from their tendency to become loosened, with irritating in many cases the skin to which they are applied, and, finally, with covering up the wound from the inspection of the surgeon. For these reasons, the use of adhesive bandages as direct applications to wound flaps to secure their apposition, should be abandoned in the great majority of cases. For purposes of supplementary support, for use outside of the dressings applied immediately to the wound, to prevent tension, to produce compression, and to insure fixation of the dressings, they are invaluable. After cicatrization has been effected they may be applied as supports to the still tender bond of union.

SUTURING.

The suture is the most certain, exact, and important of all methods of obtaining apposition of divided surfaces. Position and the various methods of bandaging are chiefly to be employed as supplementary to the suture.

The application of the suture is simply the use by the surgeon of the tailor's art to sew together the separated tissues, and by a thread to retain them in apposition until their permanent union by a bond of newly-formed living tissue can be effected.

Sutures may be applied superficially and close to the wound-margins, simply for the purpose of keeping the cutaneous edges of the wound in apposition, such stitches being technically called "stitches of coaptation;" or more deeply and at a greater distance from the wound-margins to approximate and maintain in apposition the deeper surfaces, "stitches of approximation;" or at a greater distance yet from the wound, for the purpose of relaxing the adjacent tissues so that the wound-surfaces may be brought together, and tension upon the stitches applied to keep them in apposition may be prevented—these latter constitute "stitches of relaxation."

By the use of a thread that is absorbable and sterile the deeper parts of a wound may be brought together by points of suture, which are after-

ward covered in by more superficial suturing; this is the "suture *en étage*," "layer," or "buried" suture. One form of this is the "subcuticular" suture.

For the practise of the suture there are required needles, thread, and in some cases needle forceps for the more convenient insertion of the needles in the tissues. The peculiarities of the tissues to be sewed make certain qualities important to be possessed by each of these agents; these, therefore, require consideration here.

NEEDLES.—The density and elasticity of the tissues to be penetrated by the surgical needle make it necessary that it should differ from the ordinary sewing needle by having its point flattened, and the edges immediately following the point sharp, giving the forepart of the needle the

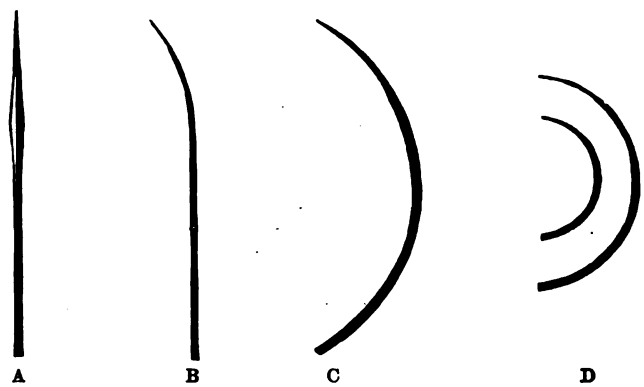


FIG. 64.—Surgical Needles.

shape of a lance (Figure 64, A). The point should be fine, and the cutting edges should extend but a short distance back from the point, and should exceed in its transverse diameter that of the shank or thread extremity of the needle. The eye should be as large as possible, to avoid delays in threading, and its edges should be well rounded, so as not to cut the thread. Their thickness and length vary greatly, according to the size of the thread to be used and the thickness of the tissues to be penetrated. The shape of the needle must vary with the locality in which the suture is to be applied. Upon a plain or convex surface, when the stitch is to be introduced but superficially, a straight or but slightly curved needle (Figure 64, A and B) is most convenient; where the tissues are to be deeply penetrated, or the wound involves a concave surface, as within

the pelvic cavity, or at the inner canthus of the eye, or the perineum, strongly curved needles (Figure 64, C and D) become necessary.

The steel of which they are made should not be too hard, lest they break easily. The chief points to be regarded in the choice of needles are that they have good points, keen sides, and sufficient temper to prevent their yielding to the force necessary to their introduction.

FIG. 65.—The needle-holder of Dieffenbach.

NEEDLE-HOLDERS.—When a suture is to be made with a small and much curved needle, or in a cavity, the needle cannot be managed by the fingers, but must be seized and held firmly in a needle-holder (Figure 66). Any forceps with short stout jaws, and long handles that can be grasped and held firmly in the hand, will answer for a needle-holder. The forcipressure forceps of Wells (Figure 34) are a good model. The

FIG. 66.—Showing manner of seizing curved needle by forceps (*Kelly*).

catch, by means of which the branches are fastened when they are closed, adds greatly to their convenience in use.

Figure 65 represents an old model, that of Dieffenbach, which in essential points is unsurpassed as a useful tool by any of the multitude of devices that have since been constructed.

The inner surface of the jaws should be cut into stellate grooves, or should be lined by pewter, into which the needle when grasped may sink

and be held securely. Many varieties of needle-holders have been devised to facilitate the introduction of sutures in deep cavities and special localities. The requirements for a needle-holder are that it shall immovably grasp the needle, that it shall be of a shape to be itself securely grasped by the hand of the surgeon, and that its mechanism shall secure the rapid picking up and quick letting go of the needle.

THE THREAD.—The suture requires that the thread-material shall be fine and smooth, sufficiently strong to stand a certain amount of strain, soft and pliable, so that it adapts itself well to the eye of the needle, easily pulled through the tissues after the needle, readily tied into a knot, and susceptible of being removed with equal readiness. The agents that are worthy of special mention as being in most general use, and as answering the purposes of the suture most satisfactorily, are threads of silk, of catgut, of silk-worm-gut, of horse-hair, and of metal.

Silk.—As fine a thread should be chosen as will bear the strain of the suture, for the finer the thread the less irritation its presence in the tissues will occasion, so that very fine ones may cause no irritation whatever, but become healed in like metal ones. The finer sizes of ordinary sewing silk are strong enough to bear any tension that ought to be put on a suture. Silk should be sterilized by boiling before using, as described on page 110.

Catgut.—Catgut is especially available for use as a buried suture. For superficial suturing it is objectionable, since it is more difficult to secure with it an exact and fine coaptation of the edges of the wound, and the spontaneous melting away of the loop in the tissues may take place prematurely. Of more importance yet is the fact that when softened in the fluids of the tissues it presents a nidus favorable for the active growth of any organisms that may have escaped the primary disinfections, or may gain access later.

When it is desired to use an absorbable suture which will resist the solvent action of the tissues for a longer time than the few days which the ordinary catgut lasts, the gut can be toughened by immersion in a solution of chromic acid; the degree of resistance to the tissues produced may be varied by different lengths of time of the immersion.

Chromicized Catgut of satisfactory quality, which I have used freely as a buried suture for a number of years, is prepared in connection with

the method of sterilization by boiling in alcohol (see page 114) as follows:

The strand of gut, after the first boiling, is allowed to dry; then it is submerged for twelve hours in a solution of chromic acid, 1:500; then dried; then boiled again for one hour; then allowed to stand for twenty-four hours, and then again boiled for one hour; then set aside in the jar of alcohol till called for.

Catgut sterilized by the ether-sublimate process may be chromicized by immersion for fifteen hours in a solution of bichromate of potassium and alcohol, fifteen grains to the pint (Morris). The bichromate should be first dissolved in one ounce of boiled water and then added to the alcohol. At the end of the period of immersion in the chromic solution the catgut is drained and placed in absolute alcohol for storage.

Silk-worm-gut.—This is made from the organ of the silk-worm which furnishes the material out of which the cocoon is woven. Each thread, as met with in commerce, is from twelve to fifteen inches in length. They are put up in bundles of 100, assorted according to the thickness of the thread. To secure each individual thread it is necessary to kill one silk-worm. All of the silk-worm-gut which comes to the American market is produced in Spain. The threads obtained are polished, transparent, and very smooth, and are especially distinguished by their great strength in comparison with their thickness; they are stronger than metal threads, and will remain unchanged in the tissues for an indefinite time. They produce no irritation, but they have the disadvantage of being somewhat stiff, so that some difficulty attends tying them in a sufficiently strong knot. To render them pliable and sterile they should be soaked some time in carbolic solution, 1:30, before being used. They are of special value as superficial sutures in regions known to be infected on account of their non-absorbent nature. They have been especially praised for cases of ruptured perineum and vaginal fistula, and fissured palate.

Horse-hair.—The pliancy, delicacy, smoothness, and non-irritating qualities of horse-hair make it a desirable substance for sutures, and it deserves more attention than it has usually received. It is strong enough to keep the lips of an ordinary wound in apposition; a double strand may be used if necessary. It remains unchanged indefinitely in the tissues, and may be permitted to remain as long as the support of a suture is re-

quired. It can be applied with the usual surgical needle, but needs more care in making a satisfactory knot than does silk. If there is any tension upon it, the first knot needs to be held by a forceps to prevent slipping while the second is being tied. It is easily removed by snipping with a pair of scissors, and withdrawal by an ordinary pair of forceps, with absolutely no discomfort to the patient, being in this respect in marked contrast with metallic sutures. Hairs from the horse's tail, selected for their size and strength, are to be preferred. They should be prepared for use by washing in an alkaline solution, and should be immersed in an antiseptic solution before being introduced. Its abundance and the readiness with which it can be obtained, costing nothing but the slight trouble of cleansing it, together with the advantages possessed by it, as enumerated, as a suture, would make the use of horse-hair general for all ordinary wounds, were it not that the silk thread is more convenient to tie and to carry by reason of its greater pliability. In default, however, of proper silk, it is a most valuable substitute.

Metal.—Fine metallic wires, of lead, of iron, or of silver, and even of other metals, may be used for the purposes of a suture; by their smoothness, pliability, and freedom from irritating properties, and the facility with which they may be sterilized by boiling, they combine in an eminent degree the qualifications demanded for such use. They may be introduced with an ordinary surgical needle like thread, although a needle whose head, from the eye to the extremity, is grooved for the reception of the wire, facilitates their introduction; they are easily fastened by twisting the ends together. They are particularly of value for wounds in which great accuracy of coaptation is desired, on account of the facility with which they can be readjusted by simply untwisting the ends, and with which, also, the tension they shall exert may be regulated by the degree to which the twisting is carried. They also tend to support and immobilize the tissues through which they pass, and contribute in this way in no mean degree to promoting early union. The ease with which they are fastened adapts them especially for use in deep cavities. There is no necessity for their early removal, and they may be left undisturbed till the parts are firmly united. Silver wire is the kind of metal thread most frequently employed. Wire made of it as fine as a hair possesses sufficient strength, and is very light, soft, and pliable. The first use of it

for sutures was made by J. Marion Sims, in the treatment of vesico-vaginal fistulæ, in 1849, and his enthusiastic advocacy of its merits in succeeding publications attracted general attention to its use in general surgery. In his "Anniversary Discourse before the New York Academy of Medicine," in 1857, he declares it to be his "honest and heartfelt conviction, that the use of silver as a suture is the great surgical achievement of the nineteenth century!" The recognition of bactericidal and chemotactic qualities in the salts of silver has suggested that a favorable influence upon the healing of wounds may in some cases be exerted through the salts generated by the action of fluids of the tissues upon silver sutures, and explains the more favorable course of wounds in which silver wire was used in pre-antiseptic days. With the precautions to avoid infection which present knowledge prescribes, any such feeble quality in the suture material is of less importance, and practically there is no difference in the amount of irritation produced in the tracks of a fine well-twisted sterile silk thread and a fine metal thread during the first eight days of their residence in the tissues. Since both the introduction and the removal of the wire demands more care than silk on account of its inferior softness and pliability, they are not so well adapted as the fine silk to unite wounds the edges of which are thin. Even in uniting the edges of such a wound as that produced in the operation for the relief of vesico-vaginal fistula, in which Sims first used silver wire with so much advantage, surgeons of the present day obtain equally good results with silk. Silk has still maintained its place, therefore, as the agent most generally employed; but for deep sutures, especially those which are applied for the purpose of relaxing the wound-borders, and for suturing bones, and whenever strong tension is to be borne by the suture, and when the suture must remain *in situ* for a long time, an unqualified preference must be given to the silver wire.

Application of the Suture.—It is important as the first preliminary, when a suture is to be applied, that the surgeon shall assure himself that the suture materials are sterile. The needles should be boiled, and whatever form of thread is deemed best should have been rendered aseptic by previous preparation, or by boiling immediately previous to using, if the material is susceptible of such treatment.

Before the introduction of a suture the wound-borders should be care-

to bring the wound-surfaces into apposition and tied into a secure knot. The various steps of this knotting of the suture are depicted in Figure 69. The suture must not be drawn so tightly as to strangulate the tissues embraced in its loop. A suture drawn too tightly lessens greatly the resisting power of the tissues embraced in its loop and favors infection with its consequent inflammation and suppuration. Nor must the suture be subjected to much elastic tension of the tissues, otherwise the tissues will cut themselves upon the unyielding thread until the suture becomes loose. When the tissues are lax the ordinary reef-knot, Figure 70, should be made as the most secure form of a knot.

If there exists much tendency to gaping in forming the first knot, the thread may be passed twice through the same noose, Figure 71, so that the adhesion of the threads is increased sufficiently to resist the tendency to retraction of the edges until the second simple knot can be tied. This is

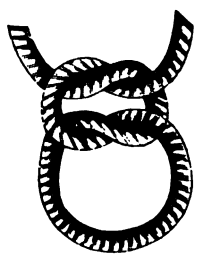


FIG. 70.—The reef-knot.

FIG. 71.—The surgeon's knot.

what is termed the "surgical knot." If the two lips can be held in apposition by an assistant while the knot is tied, the surgical knot will be superfluous.

The knot should not be tied so as to come in the wound-line, but should be tied on one side so as to press upon the sound integument, for when the knots are permitted to press directly upon the line of the wound they are liable to produce irritation.

The distance between the points of suture must vary according to circumstances, depending upon the tendency to gape of the tissues, and the importance for securing union by first intention of the most accurate apposition possible. In no case should there be allowed any gaping in the intervals between the stitches. The intervals may vary from one-eighth to one-half or three-quarters of an inch. No fixed rule can be laid down, either, as to the succession in which the stitches shall be applied, beyond

the general principle that the stitches of relaxation are to be first applied, then the stitches of approximation, and finally the stitches of coaptation. It is easily apparent when the wound-edges are brought together at what point the first stitch should be placed. In angular wounds the point of the angle should first be secured, and subsequently the stitches should be placed elsewhere, so that the borders throughout shall come smoothly together.

The stitches may be removed, as a rule, in about seven days; but unless their longer residence in the tissues is attended with evident disadvantage, as shown by a tendency to produce irritation and ulceration, it is better to leave them undisturbed for forty-eight hours longer. When there has been much tension necessary to bring the edges of the wound together, too early removal of the stitches is especially to be avoided. Ten to twelve days is time enough. By the use of aseptic sutures the necessity for speedy removal of the thread is overcome, and the needs of the new uniting tissue for support can be more exclusively considered.

To remove the stitches, the knot should be seized with a dressing forceps, elevated slightly from the integument, so that the point of a scissors can be insinuated beneath it to cut the thread beyond it. The thread is then drawn carefully out, while the tissues are steadied by the scissors pressing upon them, and traction is made upon the thread in a direction toward the line of cicatrix lest the wound be torn open anew by the proceeding. The stitches first to be removed should be those of the least importance. In general, they will be removed in the reverse order of that with which they were introduced. After their removal, the parts should be supported for a time by strips of adhesive plaster, when the wound is in a locality where they can be applied, and the line of the cicatrix and the immediately adjacent skin should be covered with a layer of collodion.

Classification of Sutures.—According to the different methods used for the successive application of the stitches, or the different devices used for exerting pressure upon the tissues, sutures are divided into *interrupted, continuous, pin, quill, bead,* and *button* sutures.

Interrupted Suture.—The interrupted suture is formed of a series of separate stitches (Figure 69). It is more generally used than any other form of suture; indeed, the pin, quill, button, and bead sutures are but forms of this suture. Stitches of relaxation and of approximation,

in all cases, require to be of this form. It is the typical suture, and all that has preceded with reference to the technique of the suture is particularly applicable to the interrupted suture.

Continuous Suture.—This suture, on account of its similarity to that used by the glover, is frequently spoken of as the "glover's suture." The stitches of which it is composed are not separate, but are made with the same needle and thread, in continuous succession, by passing the needle diagonally from one side of the wound to the other over the surface, and through the tissues, until the whole extent of the wound has been traversed (Figure 72). Though this form of suture is especially adapted for sutures of coaptation, it had until recently been almost entirely discarded, except in the sewing up of wounds of the intestines. In nearly all cases, however, it is superior to the interrupted suture for coaptation purposes by reason of its greater simplicity, the greater rapidity

Fig. 72.—The continuous suture.

with which the necessary coaptation can be secured, the more even and accurate apposition of the edges which it accomplishes, and the increased support to the whole line of the union that it gives. The resulting cicatrix will be more finely linear than can be obtained in any other way. In applying the continuous suture, a sufficiently long thread should be used, which, with a straight or curved needle, according as the peculiarities of the locality may require, is introduced at one angle of the wound, where it is tied as for the interrupted suture, and thence is carried with oblique stitches along the coapted wound-margins to the other end of the line of separation. Here the thread is fastened by leaving the superficial loop connecting the last two stitches so loose that by cutting it a free end is left which is tied to one end of the last stitch after this has been tied as an ordinary interrupted suture. For its removal, each superficial loop should be cut with the point of a scissors, converting it into as many points of

interrupted suture, each one of which should then be carefully withdrawn as before described.

PIN SUTURE.—This form of suture, Figure 73, known also as the twisted and hare-lip suture, consists in transfixing the apposed margins of a wound with metallic pins, and then, while the wound surfaces are kept approximated by pressure from the fingers of an assistant, the two projecting ends of the pin are encircled with a thread, which is then carried several times around the pin, over the line of the wound elliptically, and in the shape of the figure 8, and lastly is secured by a knot.

As a pin to be used for the purpose of this suture, the ordinary glass-

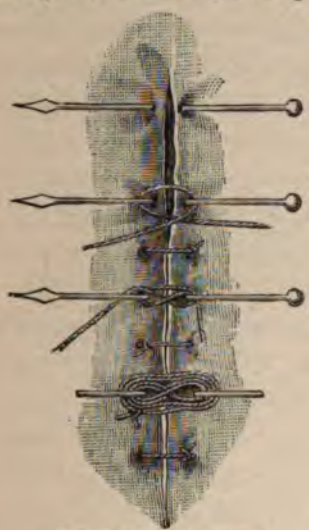


FIG. 73.—The pin suture.

FIG. 74.—Pin for twisted suture.

headed ladies' toilet-pin, Figure 74, is not surpassed by any other device. It is very sharp-pointed, and readily penetrates the tissues; it is unirritating; it is quickly procurable, and is cheap. The German insect-pin, Figure 73, which is made of brass with a ball head, and a flattened, lance-shaped point, likewise makes an excellent agent. Transfixion is effected in the same manner as in the common interrupted suture, the thumb and finger being generally quite sufficient for the purpose. The pins should be thrust as deeply into the tissues as is compatible with bringing them out again at a corresponding point upon the surface of the opposite flap. All the pins that are to be inserted should be put in place before the thread is applied, otherwise the insertion of the second pin will pull

unduly upon the first suture. The distance from the wound edges of the points of entrance and exit of the pin will be from one-quarter to half an inch. The distance between the pins will depend upon the degree to which the wound borders tend to gape, and the amount of motion to which it will be exposed. Each pin should be separately wound about with the thread, which should then be cut and tied. In place of thread, narrow rings of rubber may be used to slip over the ends, and to compress the wound-borders. The points of the pins should then be cut off with a pair of pliers to prevent their sticking into the skin. If there is a tendency evident for the ends of the pins to press unduly into the skin, this may be protected by a strip of adhesive plaster inserted beneath the extremities of the pins. The practice of taking a much longer thread and carrying it from one pin to another, making a cross likewise over the wound between the pins with the thread, as it passes from pin to pin, has the advantage of aiding their coaptation by the gentle pressure which it makes upon them; but this can be better accomplished by superficial sutures placed between the pins, as in Figure 73, which may remain to support the tissues still longer after the pins have been withdrawn. The earlier removal of the pins without disadvantage is thus made possible; this should be done in from five to seven days, even earlier if the pins show a tendency to cut their way out. When they are to be removed the wound edges should be gently pressed together by the left thumb and forefinger, applied upon the ends of the twisted loops, the head of the pin should be grasped by an ordinary dressing-forceps, by gentle rotation their adhesion in the line of their penetration loosened, and then withdrawn. The thread loops, which are glued to the skin by dried blood, may be left in place for a day or two longer, as a bond of union, until they become spontaneously detached. All the pins may be removed at the same time, or at different times. In the latter case, those will first be removed that are least useful.

The pin suture is especially applicable in cases where there has been considerable loss of integument, and where considerable strain upon the tissues is necessary to bring them together. When the parts are very movable, as in the lips and cheeks, and also when the wound involves skin that is so thin and lax that the wound edges manifest a strong tendency to roll in. A much more frequent use of the pin suture might

be made with advantage than is now usual. Though primarily it is important as a means of approximation when the divided surfaces are first brought into apposition, its secondary effect, to keep immovable and to support the united wound, is no less important, and may make its use desirable when the first indication does not call for it. The results, in general, of attempts to obtain union by first intention in wounds of any extent will be much more uniformly successful by the use of the pin suture, as a matter of routine practice, than by relying simply on the ordinary suture and bandaging.

THE QUILL SUTURE.—This suture consists in the application, on either side of the wound, at a little distance from its edges, and parallel with them, of little rods of some smooth and unirritating substance, as a quill, thick walled rubber tubing, bougie, whalebone, or soft wood, around

FIG. 75.—Quill suture. In course of application.

FIG. 76.—Quill suture. Application completed.

which threads passed deeply across the wound are looped, so that when they are drawn upon and tied, the pressure of the rods brings and holds together the deep parts of the wound, and relaxes the superficial parts, which are also secured by superficial stitches of the interrupted or continuous suture. The arrangement is shown in Figure 75 and Figure 76.

In making this suture, several needles should be threaded by passing both ends of the thread through the eye of the needle, so as to form a loop on the middle of the thread. The double thread is then to be passed, as deeply as may be necessary, through the wound-borders as for an ordinary interrupted suture. A sufficient number of threads having been introduced, instead of crossing them and tying, a rod is slipped through the loops on the one side of the wound, which are then tightened

from the other side by drawing on the free ends. A similar rod is then placed between the free ends of the threads, and upon this they are firmly tied, beginning with the central threads, which are drawn down upon the rod until by its pressure the wound surfaces are brought into close apposition. A secure knot is then tied, and the application of the apparatus is complete. This form of suture was used by the older surgeons for closing deep muscular wounds, as those of the thigh and abdomen; and by later surgeons more particularly for the repair of lacerations of the perineum. It is efficient both as a suture of approximation and relaxation, but for these purposes has been mostly superseded by the bead and the button suture in some form, or has been rendered unnecessary by the use of buried sutures. In wounds in situations where the additional support of compresses and bandages are impracticable, it will, however, always remain as a device of great value for securing primary accurate deep apposition and consecutive immobilization and support during the healing of the wound. For its removal, after five to seven days, the loops are cut with scissors on the one side, and the threads drawn out on the other.

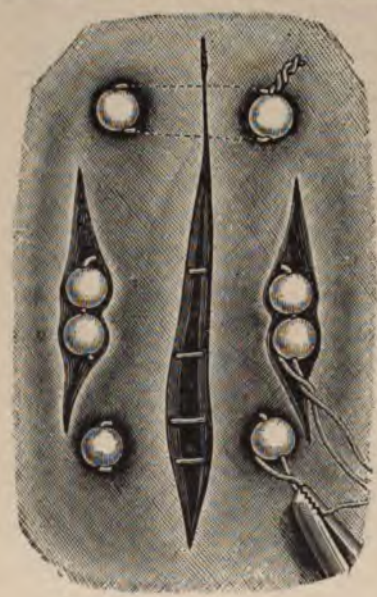


Fig. 77.—The bead suture.

The Bead Suture.—This is an interrupted suture in which two sutures are joined in one so that a bead at either lateral extremity of the suture has a wire or thread passing through the centre of the bead (Figure 77). The twist of the two ends of the wire enables the operator to tighten or loosen the tension after the suture line is closed. This is a very desirable quality of a stitch in a situation like that of the interior of the mouth, the stitch having no covering, and the suture line having no possible support except that of the stitches themselves. This suture is equally applicable to wounds in the vagina, where any support to the stitches is impracticable.

THE BUTTON OR PAD SUTURE.—For the purpose of securing relaxation of the more distant tissues, so that the wound-surfaces may be approximated and coapted, an efficient device is some form of metal plate, or button, or pad of folded gauze, placed on either side of the wound at

FIG. 78.—Lead button for stitch of relaxation (*Cheyne*).

appropriate distances, and joined by silver wire which is passed deeply through the tissues from plate to plate across and at the bottom of the wound. Traction upon the wires suffices to draw together the tissues pressed upon by the plates and to relax the intervening tissues. Whenever a considerable gap exists, such sutures are of great value in facili-

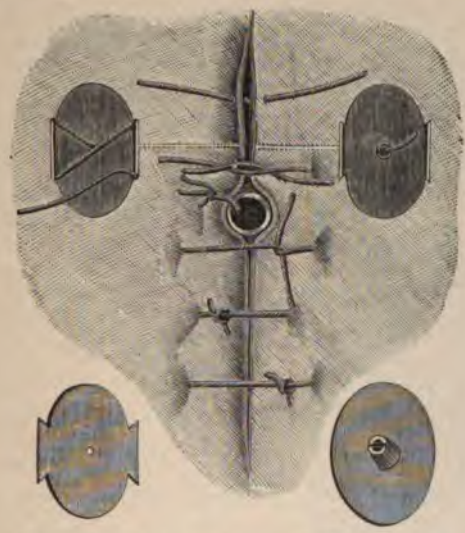


FIG. 79.—The button suture applied (*MacCormac*).

tating healing, and should generally be employed. Various forms of plates have been used. None are more simple and efficient than the form devised by Mr. Lister, Figure 78, which consists of a flat plate of lead, about one-twentieth of an inch in thickness, cut of an oval form,

with lateral wings, which are turned up, and afford projecting edges about which the end of the wire is wound in a figure-8 form, while the wire for the suture passes out through a hole that has been perforated

FIG. 80.—Arrangement of stitches of relaxation, of approximation, and of coaptation to close wound after removal of mamma and axillary glands (*Cheyne*).

through the centre of the plate. Figure 79, from MacCormac's "Antiseptic Surgery," illustrates the method of the application of this lead plate or button. On the one side the wire is seen to be secured by winding it about the projecting wings as described; on the other it is secured by a split shot which has been clamped upon it.

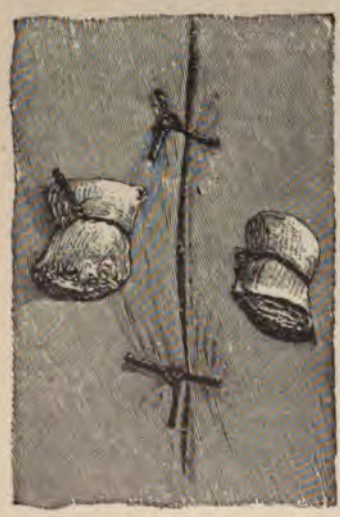


FIG. 81.—Gauze-pad suture.

The arrangement and function of the button stitches of relaxation is well shown in the accompanying illustration from Cheyne's "Antiseptic Surgery." (Figure 80.) The use of a roll of gauze as a pad to take the place of buttons or plates as described in the preceding paragraphs is shown in Figure 81. Such a pad can be extemporized at any moment, and being equally efficient, is perfectly suitable for general use in dealing with wounds on the outer surface of the body.

DEEP SUTURING BY SUPERIMPOSED LAYERS OF SUTURES, ONE ABOVE THE OTHER.—In deep wounds where different planes of tissues are opened into, and in all deep wounds where exact apposition of the wound-surfaces

is not otherwise easily and certainly to be obtained, the tissues may be sutured together, layer by layer, or at such irregular points as the necessities of the case may seem to require, by using for the suture material sterilized catgut. Thus in a wound opening into the peritoneum, independent sewing together of the peritoneum, of the muscular layers, and lastly of the skin and subcutaneous tissue, could be done. In a similar way, in bone operations, the peritoneum, muscles, and the skin would be united by three sets of sutures, one lying over the other. This method greatly restricts the use of drainage tubes, since it with certainty prevents the formation of any cavities to be drained; by this method even an amputation wound of the thigh can be thoroughly closed, without a drain, and union by first intention secured under a single dressing.

THE CROSSED SUTURE.—In wounds which involve several layers of tissue of different degrees of tonicity and tension, as in wounds of the abdominal wall, a separate means of approximating and holding together different layers is of importance, and the possibilities of too early absorption of an ordinary catgut suture, with consequent gaping of the deeper tissues, are so great that some device whereby perfect and continued apposition of all parts of such a wound, layer to layer, should be secured is often important. For this purpose silk-worm-gut, introduced after the manner of the "crossed suture" of Fowler, is efficient. To apply this, both ends of the thread are armed with needles of the proper curve, and the separated edges of the deeper layers of the wound are each pierced from within outwards with a needle and its thread; then the superficial layer of the wound edges is pierced by the needle which was used to pierce the opposite side of the deeper part of the wound; the threads cross each other by this manœuvre, and when the ends of the thread which perforate the skin are drawn taut and tied a series of figure-8 loops is formed, which insures the coaptation of the deeper parts of the wound as long as the suture is left in place. This crossing of the suture may be combined with quills or buttons with advantage when a wound is deep and gaping, and the facilities for buried sutures are wanting. This method of suturing is especially of value, also, when it is important to secure rapid closure of a wound.

THE SUBCUTICULAR SUTURE.—Whenever it is possible to employ buried sutures for closing the deeper part of a wound—that is, in the

presence of adequate facilities for the prevention of infection, and when the general condition of the patient is not such as to make urgent the speedy closure of a wound—the superficial part of the wound may be brought together by a running suture so applied as to pierce only the subcutaneous tissue and not to penetrate the skin proper at all; this constitutes the "subcuticular" suture. By its use there is prevented any perforation of the cuticular layers and the skin follicles in which organisms always remain that have not been reached by the means of prelimi-

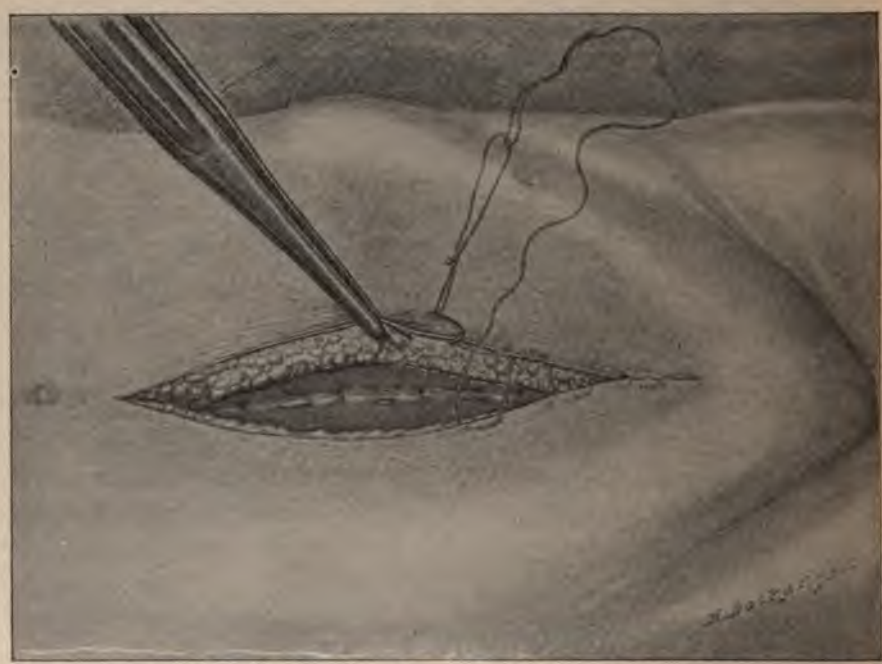


FIG. 82.—The application of the subcuticular suture (*Kelly*).

nary skin disinfection used, however thorough, and which are often the cause of later wound-infection. To this degree, therefore, the probabilities of an aseptic course of the healing are increased. The technique of the application of this form of suture is shown in Figure 82.

Silk or linen thread is the best for use. It is threaded into a well-curved needle, which is first made to penetrate the skin at about one inch beyond the upper angle of the wound, and is brought out into the wound through the deeper layer of the corium in the angle; it is then passed as a continuous suture down the wound, seizing in its loop only the tissue

just under the skin, and never appearing on the skin surface until the lower angle is reached, when it is finally brought out through the skin at the same distance from the wound as it entered it above. By drawing firmly on the two ends of the thread thus introduced, the skin margins throughout its whole extent are brought into and remain in coaptation. This thread should be left undisturbed for from twelve to fourteen days, after which time it will be found possible to easily draw it out by traction upon one end of it.

SECONDARY SUTURES.—There occur not infrequently surgical conditions associated with wounds which render so improbable the undisturbed course of healing if suturing is attempted, that the prudent surgeon refrains from the attempt and leaves the wound to heal by granulation. In certain instances after the granulating process has become well advanced, the granulating surfaces may be brought together by sutures and adhesion and union secured; when this is done a *secondary suture* is said to have been applied. For secondary sutures such non-absorbent material as silk-worm-gut or silver wire is especially fitted. The conditions most frequently met with that call for this treatment are: *a*, wounds made in inflamed or suspicious tissue; this involves at once wounds made for the evacuation of abscesses or for the débridement of dense superficial tissues which are confining infected secretions; *b*, wounds made for the exposure of tuberculous foci in bones and joints in which the complete removal of all infected tissue is uncertain and in which the use of iodoform gauze tampons is desirable, and *c*, all wounds involving or in the near vicinity of the mouth and anus and urinary passages, from which it is impossible to keep infecting secretions.

In conclusion, it will be well to repeat that while in different wounds different conditions calling for differing devices for obtaining apposition of the divided surfaces may be found, the great principles will always be the same, and must each be regarded, if the best result possible is to be obtained. These principles are embodied in the three words, *relaxation*, *approximation*, and *coaptation*. When these have been secured, the next duty of the surgeon in the treatment of a wound is to protect the injured parts from disturbance of every kind till repair is complete.

CHAPTER XI.

PROTECTION AGAINST DISTURBANCES OF HEALING—ANTISEPTIC DRESSINGS.

Gauze—Carbolated—Iodoformized—Medicated—*Cotton-wool*—Sterilized—Hygroscopic—*Tow*—*Jute*—*Turf-moss*—*Sawdust*—*Wood-wool*—*Paper-wool*—Lister's Protective—External Impermeable Envelope—Bandages—*Application of the Dressings*—The Method of Lister—The Ordinary Aseptic Wound-Dressing—The Dressing of Open Wounds—Changes of Dressings.

In the further history of a wound, it will be necessary that protective dressings be applied, by which it shall be kept from septic infection, from direct mechanical violence, and from motion, and by which also the compression and warmth needed to promote nutrition shall be maintained, until healing is complete.

Septic infection is to be guarded against by covering the part with soft and absorbent materials that will receive and keep aseptic the discharges that drain away from it, and that will protect the wound from the access to it of infected material from without. For this purpose many substances may be found useful. Among those more commonly employed are gauze, cotton-wool, turf-moss, tow, jute, and sawdust. The natural absorbent properties of these materials are such that bloody or serous discharges which reach the surface are greedily taken up by them, and unless some source of renewed or continued discharge is present, that which escapes into the dressings soon becomes dried and unfitted for bacterial life. They are first to be rendered sterile by moist heat. In dealing with infected wounds it is further desirable to saturate them with a sufficient amount of some antiseptic material to destroy or to render inert the septic matter of the discharges. Materials thus prepared constitute *antiseptic dressings*, the preparation of the more important of which will next demand attention.

ANTISEPTIC DRESSINGS.

Gauze.—Loosely woven cotton cloth (gauze, cheese-cloth) is more largely used as an absorbent dressing than any other material, and is technically known as "gauze." It was the foundation of the great mass

of the antiseptic dressing introduced by Mr. Lister, who first mentioned it in the *British Medical Journal* for January, 1871. The cloth should first be prepared by boiling it in a weak solution of carbonate of soda and chloride of lime, to thoroughly cleanse and disinfect it. This may be done in an ordinary wash-boiler. The cloth is then dried, when it will be found to have become much more absorbent than before. Thus prepared, it may be impregnated with various antiseptics, and kept for use.

Carbolated Gauze.—Gauze impregnated with carbolic acid was the material generally employed by Mr. Lister as a dressing to guard against the entrance of causes of fermentation into a wound after an operation, and is to be provided whenever the so-called Lister dressing is to be applied. It was prepared by saturating the gauze with an equal weight of a mixture containing carbolic acid, 1 part; common resin and paraffin, each 4 parts, melted together in a water-bath. Carbolated gauze cannot be kept for any length of time without deterioration, by reason of the evaporation of the carbolic acid. It cannot be kept in permanent store. Hence only that which has recently been prepared should be used.

Iodoformized Gauze may be prepared by roughly rubbing the crystals into the meshes of the cloth. Gauze thus prepared constituted the ordinary "absorbent iodoform gauze" of Billroth. In preparing it the loosely crumpled sterilized gauze should be put into a sterile receptacle—a wash-basin boiled—and plentifully sprinkled, by means of a pepper-box, with the iodoform powder. This should then be worked in with the hands until the whole of the gauze is uniformly yellowed by the powder. Then the excess of the iodoform is to be gotten rid of by shaking, after which it is ready for use. It should be kept in sealed flat glass jars. The amount of iodoform retained by the gauze after the shaking will be from ten to twenty per cent. An ounce of iodoform will impregnate thus between four and five yards of gauze. The gauze thus prepared should be sterilized by heat before using. Other methods of preparing sterile iodoformized gauze are given on page 123.

An "adhesive gauze" may be prepared by soaking the gauze in an alcoholic solution of resin, to which glycerine is added, and dusting the iodoform upon the sticky surface left after it has been wrung out and half dried, just as in the preparation of the absorbent gauze. For priming the gauze the following formula is used:

Resin.	100 parts.
Alcohol (95 per cent.)	1,200 "
Glycerine.	50 "

Nearly four times as much iodoform is retained by this gauze as by the unprepared fabric. It is of especial value in dressing wounds in the cavity of the mouth.

Gauze can be impregnated with any of the antiseptic solutions or powders, at the judgment of the surgeon. All of the iodine, bismuth, and zinc compounds mentioned in Chapter V. are used in this way.

COTTON-WOOL.—Ordinary cotton-wool, as it is found in the shops, serves many purposes as an external protective envelope, applied over a mass of sterile absorbent gauze as the dressing in immediate contact with a wound. As a matter of routine it is desirable that the cotton thus employed should first be sterilized by heat. If an absorbing quality is desired for the cotton thus employed, it must be first rendered hygroscopic by boiling it in an alkaline solution and drying. It is thus prepared on a large scale by different manufacturers in this country, and in trade is known as "absorbent cotton." For surgical use it is further charged with different antiseptic drugs, especially boracic and salicylic acids.

Absorbent cotton is much restricted in its availability as an absorbent wound dressing from the fact that the portion of the cotton immediately over the wound soon becomes matted together by the viscid wound-discharge, and forms thereafter an impervious covering under which further discharges are retained. For this reason it is rarely employed as the first dressing, and since for the secondary or external protective envelope the less costly ordinary cotton-wool is just as good, the need for the hygroscopic cotton is not great. It may be used for sponging purposes, but pieces of gauze are much more convenient and efficient for that purpose.

Cotton-wool may be sufficiently charged with any of the antiseptic powders by simply rubbing into the meshes of the wool, at the time it is to be used, the dry fine powder. Borated and salicylated cottons may be prepared according to the formulæ subjoined.

Borated Cotton.—Hot water dissolves fifteen per cent. of its weight of boracic acid, but on cooling precipitates all but four per cent. If the cot-

ton be treated with an equal weight of a saturated hot solution of boracic acid and then dried, it will remain permanently charged with fifteen per cent. of the antiseptic substance, which is a desirable strength to have to insure its antiseptic properties. Borated cotton thus prepared has the acid intimately incorporated into the substance of its fibres and is free from loose particles of the crystals lying among its meshes.

Salicylated Cotton.—Salicylic acid requires 300 parts of cold water for its solution; boiling water dissolves it in the proportion of 1 to 25, but much of a given quantity of the acid is volatilized by the heat of such a solution, making its permanent strength unreliable.

Alcohol takes it up in large quantity, and a dilute spirit makes the best menstruum with which to charge a dressing. As the fine crystals deposited in the interstices of the wool are liable to shake out, a small proportion of glycerine should also be added. The following formula will insure the preparation of the 10 per cent. strength:

Glycerine	2	parts by weight.
Water	100	" "
Alcohol	20	" "
Salicylic acid	2	" "
Cotton-wool	20	" "

The solution of the acid having been made in the menstruum, with the aid of very gentle heat, the mixture should be placed in a flat vessel, in which the wool should be laid in layers, each being thoroughly saturated before the next is superimposed. When the whole mass has thus soaked for about ten minutes, it is turned upside down, the layers taken off in the order that they were put on, and laid aside to dry, flat, and in a warm room.

Tow.—Flaxen or hempen fibres may act as substitutes for the cotton, and may be treated in the same ways. They are inferior in absorbent qualities, and are less soft in texture than the cotton. Impregnated with tar they form *oakum,* which forms an excellent wound-dressing in many conditions, but it has only feeble antiseptic properties. Oakum may be charged with other antiseptics in addition to the tar, and be of especial value as a cheap material to form the outer layer of dressings. Its fibres

are too harsh to make it a desirable substance to place in immediate contact with a wound.

JUTE has been largely used as a wound-dressing on account of its cheapness and great absorbent power. This is a vegetable fibre obtained chiefly from Bengal, and brought in large quantities to the New York market, where it is used in the manufacture chiefly of mats and coarse woven stuffs. It is one of the most cheaply raised and prepared of all fibres. The best qualities, which alone are suitable for surgical use, have a clear white, yellowish color, with a fine, silky lustre. The fibres are soft and smooth to the touch, and are fine, long, and uniform. They are composed of from thirty to one hundred fibrillæ, flattened in external shape, and tubular in the centre, which well adapts them for the absorption and retention of an antiseptic medium.

Jute may be impregnated with various antiseptics in the same ways as have already been described for cotton-wool. It should be cleaned before impregnation.

TURF-MOSS (Sphagnum cymbifolium), dried and cleaned, is very absorbent, not only by reason of the capillary spaces between its fibres, but also by reason of the cell-spaces of its own substance, in this respect resembling marine sponges. It may be sterilized by heat, and when moistened it forms a light, soft, elastic mass that forms an ideal wound-dressing. It has been largely used, especially by German surgeons, in whose land the moss is easily obtained in large quantities. For use the moss is made up into pads or cushions of various sizes enclosed in gauze.

SAWDUST.—As a cheap and readily obtained absorbent dressing, coarse pine sawdust, made into pads with a gauze envelope, answers well. Such sawdust pads absorb pus better than gauze or cotton. They may be sterilized by heat, or by immersion in sublimate solution.

WOOD-WOOL, a material advertised largely as a wound-dressing, is prepared from pine shavings and splinters softened by maceration in water and then rubbed through a wire sieve to secure finer division, then dried. It makes a fluffy, soft, absorbent material. Like moss and sawdust, it is used made up into pads with gauze. It is susceptible of being rolled out into thick sheets, which are convenient for cutting up into pads of any size or form. It resembles hygroscopic cotton in its properties, like which material also the layer of it immediately over a wound soon be-

comes matted together by viscid wound-discharges, destroying its further efficiency as an absorbent. For this reason its range of usefulness as a wound-dressing is limited.

Paper-wool is composed of thin manila paper cut into narrow strips. It is used in cushions of various sizes, made by stuffing gauze bags with the strips. These cushions are sterilizable by heat. They are soft, compressible, and greedily absorbent of water, but become quickly saturated and collapse. As a protective dressing they are admirable. They may be used with advantage also as an immediate application to a sutured wound from which no discharge is expected.

The Protective.—Whenever the direct contact with the wound-surfaces of the dressings would chemically or mechanically irritate them, as is especially the case with those that are impregnated with carbolic acid, it is best to apply, over the exposed wound-surface, a layer of some aseptic neutral and unirritating substance as a protective, over and around which the absorbent dressings shall be placed. Such a layer will be of use also in preventing the dressing from sticking to the wound, and in preventing the formation of scabs, and the consequent possible retention of the discharges. The material so used is, in general parlance, distinguished by the technical name of the *Protective*.

The special material employed by Mr. Lister, in connection with his carbolic acid dressings, consisted of oiled silk coated with copal varnish. When this is dry a mixture of one part of dextrine, two parts of powdered starch, and sixteen parts of cold watery solution of carbolic acid (1 to 20), was brushed over the surface. The rationale of this method of preparation is the following (Cheyne): Oiled silk alone is better for the purpose of a protective than gutta-percha tissue, because carbolic acid does not so readily pass through it. It does, however, do so, and therefore copal varnish, which is almost absolutely impermeable to carbolic acid, is added. As, however, the fluid collects on this as on a duck's back, leaving intervals between each drop on which dust may fall and escape the action of the acid, the dextrine solution is added, and the result is that when moistened the whole surface of the protective remains uniformly wet. The use of the carbolic acid in the dextrine solution is not to add any carbolic acid to the protective, but because it is better than water for enabling the dextrine to adhere to the varnished oiled silk.

For the same reason the powdered starch is added. The original carbolic acid flies off very quickly from the protective, leaving a material containing no antiseptic in its substance.

This protective should always be dipped in an antiseptic solution (carbolic acid 1 to 40, or corrosive sublimate 1 to 1,000) before being applied to the wound-surface.

Although the dextrine-copal-oiled silk of Lister is a superior form of protective material, it is not indispensable, and, when it cannot be conveniently obtained, may be substituted with very good effects by ordinary rubber tissue.

Cheyne calls attention to the frequent error of putting on too large a piece of protective. There is nothing antiseptic in its substance, and it protects the discharge beneath it from the action of the antiseptic in the other dressing materials. Therefore if at any part it projects beyond or comes close to the edge of the dressing, it allows the causes of putrefaction to spread inward beneath it, and prevents the antiseptic from acting on this putrefying discharge. It is therefore a very good rule, he remarks, having covered the wound with sufficient protective, to look on this protective as a wound, and to be as careful in having the gauze dressing overlap it in all directions as if it were itself the wounded surface. Where there is very little space for overlapping, no protective ought to be applied. It is better to have somewhat slower healing than to have putrefaction spread into the wound.

With the disuse of absorbing dressings charged with irritating drugs, the special indication for the use of this protective layer of Lister has ceased, and it is rarely used except in the case of broad, open granulating surfaces, and in cases of skin grafting, to prevent the adhesion of the dressing to the granulations or to the strips of cuticle as grafts. Such an impermeable layer applied upon the skin keeps the surface covered by it in a water-bath, retains always some of the albuminous secretions from the wound, and presents the most favorable possible conditions for the active growth of epidermal organisms. It should, therefore, never be used to cover a sutured wound. For it may be substituted with great advantage strips of gauze impregnated with such an unirritating and sterile restrainer of bacterial activity as oxide of zinc, or any of its congeners (Chapter VI).

EXTERNAL IMPERMEABLE ENVELOPE.—In the Lister dressing, for the purpose of arresting the evaporation of the volatile antiseptic, and to prevent the secretion which soaks through the dressing from becoming exposed to the air and becoming septic, the absorbent dressings were enveloped in a thin impermeable material called *Macintosh* cloth.

The use of such an impermeable external envelope is open to the same objections as have been mentioned in connection with the protective. It has been entirely discarded as a part of wound-dressing, and its place has been taken by a layer of sterilized cotton-wool, which permits the free transpiration of moisture from within and effectually guards against the access of infecting organisms from without.

BANDAGES.—For the purpose of adjusting and retaining the dressings in place, bandages of various widths are required. If the case requires their direct application upon the deeper parts of the dressing, they should be made of sterilized gauze.

APPLICATION OF THE DRESSINGS.

THE METHOD OF LISTER.—As the method perfected by Mr. Lister was the first in which the indication for protecting wounds from contamination with infecting organisms, and for keeping their discharges free from putrefaction was accepted as the chief end of treatment, and was successfully accomplished, the details of the arrangement of the dressings adopted in this method for securing continued protection after the arrest of the hæmorrhage, the cleansing of the wound, its drainage, and the apposition of its surfaces had been accomplished, are worthy of description, although they are defective in many respects when measured by later knowledge of bacterial life, and have been substituted by simpler and more efficient methods. They must always, however, retain great historical interest. The following is Cheyne's description of the details of the application of these dressings ("Antiseptic Surgery," pp. 87-93):

The dressing employed is the carbolic gauze; and to prevent the irritation of the healing edge of the wound by the carbolic acid, a piece of protective is interposed between the gauze and the wound. This protec-

tive is cut a little larger than the wound, and it is well to cover the buttons with a little bit also, in order to prevent the threads of the gauze from becoming entangled in them. This protective need not extend over the orifice of the drainage-tube, as its essential object is to protect the healing part from the irritation of the carbolic acid. Outside the protective a piece of gauze wet in the carbolic lotion (1 to 40) is applied so as to overlap the protective in all directions. The reason for this is that dry gauze is apt to receive dust on its surface before being used, while at the ordinary temperature of the atmosphere but little carbolic acid is given off from the gauze, certainly not enough to destroy immediately the activity of the septic particles in the dust. But if the piece of gauze applied next to the protective be moistened in the 1 to 40 solution, this dust is at once deprived of septic energy, and we apply over the wound a layer of pure and powerfully antiseptic material. The piece of wet gauze and

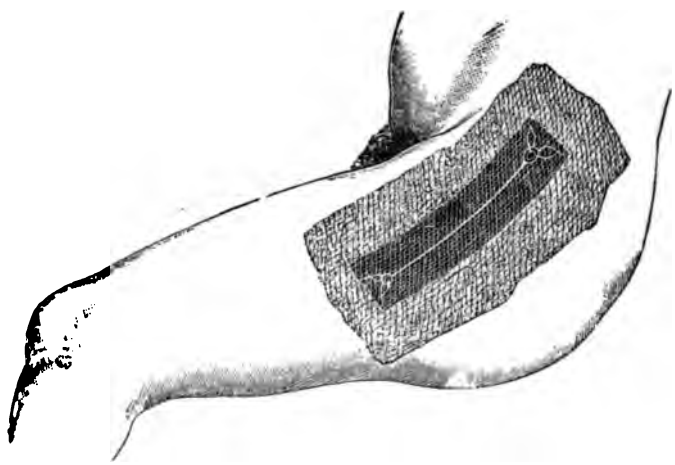


FIG. 83.—Protective and deep dressing applied to wound made in excision of the hip-joint (*Cheyne*).

the protective go by the name of the deep dressing (Figure 83). This deep dressing may, in some cases, and more especially where catgut stitches and catgut drains are used, be left for several days undisturbed. If the deep dressing be thus left on, it must be remembered that the deep piece of gauze loses all its carbolic acid very soon, and that, therefore, it must be treated as a wound—*i. e.*, in renewing the dressing this deep part

must be overlapped in all directions by a piece of wet gauze, and that again by a dressing of suitable size.

Having arranged the deep dressing in a suitable manner, any hollows which exist in the neighborhood of the wound are filled up with carbolic gauze, and special masses of this material are placed where the greatest amount of discharge is expected. Outside this a large gauze dressing, consisting of a piece of gauze of sufficient size folded in eight layers, beneath the outer layer of which is placed a piece of macintosh cloth, is applied. The size of this dressing varies according to the amount of discharge expected, but in all cases it must extend well beyond the deep dressing in all directions. This dressing is fixed on with a suitable bandage of gauze or ordinary cheap muslin. The dressing is pinned round its edge to the bandage. Care must be taken not to put pins through the macintosh at any part except at its edge. To prevent the edge of the dressing from becoming separated from the skin, and air passing into the space thus formed, the edges of the dressing are surrounded with an elastic bandage, put moderately on the stretch, its general arrangement varying with the situation.

As a rule, the dressing ought to be changed entirely on the following day, the deep part as well as the superficial. It is well to change the deep dressing in order to see that none of the stitches are too tight, and that the drains are acting properly. After the first day the deep dressing need not be touched, unless the patient is complaining of uneasiness, or unless the surgeon wishes to see the wound for the purpose of removing stitches or drain. If the deep dressing is not changed, great care must be taken to have an efficient spray playing over the part.

In changing the dressing the spray is used, and also 1 to 40 carbolic lotion, in which a piece of loose gauze and protective are put before the dressing is begun. The elastic bandage is first removed, and then the patient or an assistant places his hand over the centre of the dressing while the bandage is being cut, so as to prevent the dressing being lifted up and air pumped in. Then the surgeon, having purified his fingers, and having turned on the spray, lifts the edge of the dressing carefully, taking care that the spray passes into the angle between the dressing and the skin. Having removed the superficial dressing, he again dips his fingers, and then removes the deeper parts and exposes the wound.

If nothing is wrong, he immediately applies fresh protective and wet gauze, and then washes the parts round about, as far as the discharge has extended, with 1 to 40 carbolic lotion. The edge of the wound is not washed or exposed to the action of the spray longer than is absolutely necessary. A fresh dressing is applied as before described.

The next dressing takes place on the following day at visit, if there is any discharge at the edge of the dressing, or if the wound feels uneasy. The rule for changing the dressing is: Change if discharge is through at the visit hour, or if there be any other reason for it; if not, leave the dressing till the next day at visit, and then follow the same rule.

Never leave a dressing unchanged longer than a week. By that time most of the carbolic acid has passed off by evaporation, and therefore, if the discharge once came to the edge, putrefaction could spread inward with great rapidity. And it would not be necessary for the discharge to appear at the edge in order to have putrefaction of the wound, for the sweat collecting beneath the dressing permits the mutiplication of septic particles in it, and thus they may reach the wound.

The Ordinary Aseptic Wound-Dressing of the present day is a very simple matter in itself, but it presupposes the efficient use of all the cares for preventing infection of the wound mentioned in Chapter VI. Along the line of suture is placed a strip of sterilized gauze impregnated with oxide of zinc, nosophen, aristol, or such agent. (A film of silver foil has also been suggested for this purpose.) In default of the medicated gauze, a small amount of the powder itself may be sprinkled on. Then is laid on a pad of sterilized gauze, containing from eight to ten thicknesses of the gauze, and wide enough to extend from three to four inches in every direction beyond the wound. If drainage has been provided and much discharge is expected, an increased thickness of gauze should be placed over the drain-openings. Moist gauze will take up viscid secretions more readily than dry gauze, and for this reason it is well to use gauze wrung out in sterile saline solution or in boro-salicylic solution to place over the drains. Finally a copious layer of sterilized cotton-wool is adjusted so as to cover in the gauze, and the whole is secured in place by an ordinary roller bandage.

Open Wounds. No other dressing will give such uniformly good results in the treatment of open wounds as the iodoform. Nor is any

method of dressing such cases so simple in its application, or requiring such infrequent changes.

Open wounds, after being cleansed, are to be simply filled with absorbent iodoform gauze. In irregular cavities, the first layer of the gauze is cut in strips and introduced into all fissures and compartments; it is important that the iodoform gauze be brought in contact with the entire wound-surface; into the remaining cavity layers of gauze are loosely packed till the space is filled to the level of the integument. The dressing is then completed by sterilized gauze, cotton, and bandages, exactly as in closed wounds. Healing takes place by granulation with but very little suppuration.

Change of Dressings.—The dressings may remain unchanged indefinitely in the absence of special symptoms or conditions that may suggest interference. In a closed wound, in which primary healing has taken place, without complication, the dressing should be removed at the end of ten or twelve days, the sutures removed, and a second supporting and protecting dressing of strapping and gauze applied, to be finally discarded at the end of another two weeks.

When drainage is provided and the primary discharge of bloody serum is copious, it may be best to remove the saturated dressings at the end of forty-eight hours, or even earlier in special cases, and apply fresh absorbent dressings. In other cases the dressings should be left undisturbed until the fifth or sixth day, by which time gauze drains, if used, are in the best condition for removal, and tube drains may be dispensed with until suppuration has developed.

A change of dressing for inspection of the wound becomes necessary whenever the temperature presents an irregular curve, with evening rises of two or more degrees, possibly due to infective processes in the wound, and to retention of irritating secretions. If inspection of the wound should confirm the suspicion of wound-infection, the treatment described for septic wounds should be instituted, involving in most cases the removal of sutures and the conversion of the wound into an open one, and subsequent more frequent changes of dressings, according to the special conditions that may present.

With regard to the use of absorbent materials other than gauze and cotton, and the use of particular antiseptic agents, the convenience or

caprice of the surgeon will determine the choice in many cases. All other things being equal, those applications which are the simplest, the least expensive, the most readily obtained, and which need the least frequent changing, merit adoption for general use. The particular indications which special wounds present will be considered in the chapters devoted to those wounds.

CHAPTER XII.

PROTECTION AGAINST DISTURBANCES OF HEALING—(Continued).

REST.

***Position*—*Compression*—*Immobilization*—Wire-gauze Splints—Plaster-of-Paris Splints—Shells—Encircling Plaster-bandage—Fenestrated—Interrupted—Change of Dressings—Anodynes.**

REST, as nearly absolute as possible, is of great importance in favoring the undisturbed and rapid healing of a wound. This involves protection from motion and from external mechanical violence, the control of muscular spasm, and every means which will tend to insure quietude and comfort in the wounded part. The means by which rest is to be obtained, include Position, Compression, Immobilization, Infrequent and Careful Dressings, and Anodynes.

POSITION.

That position should always be selected which will be comfortable to the patient. An uncomfortable position provokes general restlessness and local muscular spasm. Attention to the comfort of the part cannot be too carefully regarded. This position will always be one in which the parts are relaxed, and the return circulation of the blood to the heart is favored. The limbs, if wounded, should be slightly flexed and elevated. In wounds of the lower extremity this is of more importance, and demands more care in its accomplishment. The foot should be raised to a higher level than the knee, and the knee than the hip; in cases of severe wounds the limb should be swung so that movements of the trunk should not disturb the injured limb. The relations of position to drainage should be kept in mind, and in the arranging of the means for drainage, whenever possible, the drains should be so placed as to be most efficient when the part shall have been placed in the position of the greatest comfort.

COMPRESSION.

Gentle, uniform, and continuous pressure is of great value in promoting rapid repair after injury. It restrains excessive "active hyperæmia," limits effusion, and promotes absorption of effusions already present. When properly applied it prevents muscular spasm, and thus becomes a valuable auxiliary in securing rest to the part. A greater and more methodical application of pressure than is needed for maintaining simple apposition of the separated parts is required to obtain the full power of compression in favoring the repair of a wound. Compression should be smooth and uniform, gentle but firm, while any constriction is carefully avoided. In most cases it may be best effected by surrounding the wounded part with layers of cotton-wool, and applying compression with roller-bandages. The wool moulds itself exactly to the limb, and by its elasticity tends to evenly distribute the compression exercised by the bandage and to keep the pressure continuously uniform. In cases of wounds of the limbs the bandage should be applied first at their distal ends, and carried up evenly and carefully over the wounded part, and above it for some distance. The means of compression will also be important elements of the means of immobilization, in the consideration of which the value of the compression itself is apt to be lost sight of. Experience, however, has shown that immobilization without methodical compression is more imperfectly and slowly efficient in promoting repair and delaying wound-disturbances than when both are combined. Perfect quiet and uniform compression are the most conspicuous agents which can reinforce the natural reparative energy of a part.

IMMOBILIZATION.

Immobility is to be secured by the judicious application of splints, pads, and bandages. A splint, whenever applied, should assist in furnishing equable and uniform compression and support, as well as fixation. For this purpose the various forms of plastic splints offer great advantages in many cases in which, as in penetrating wounds of joints and compound fractures, fixation of an entire limb is necessary. Such splints accurately take the shape of the parts, forming a firm mould that encases

and fixes the limb without pressing unduly at any one point. As a result such splints are borne with comfort, and thus indirectly contribute still more to the well-doing of the wound. It is unnecessary to attempt to

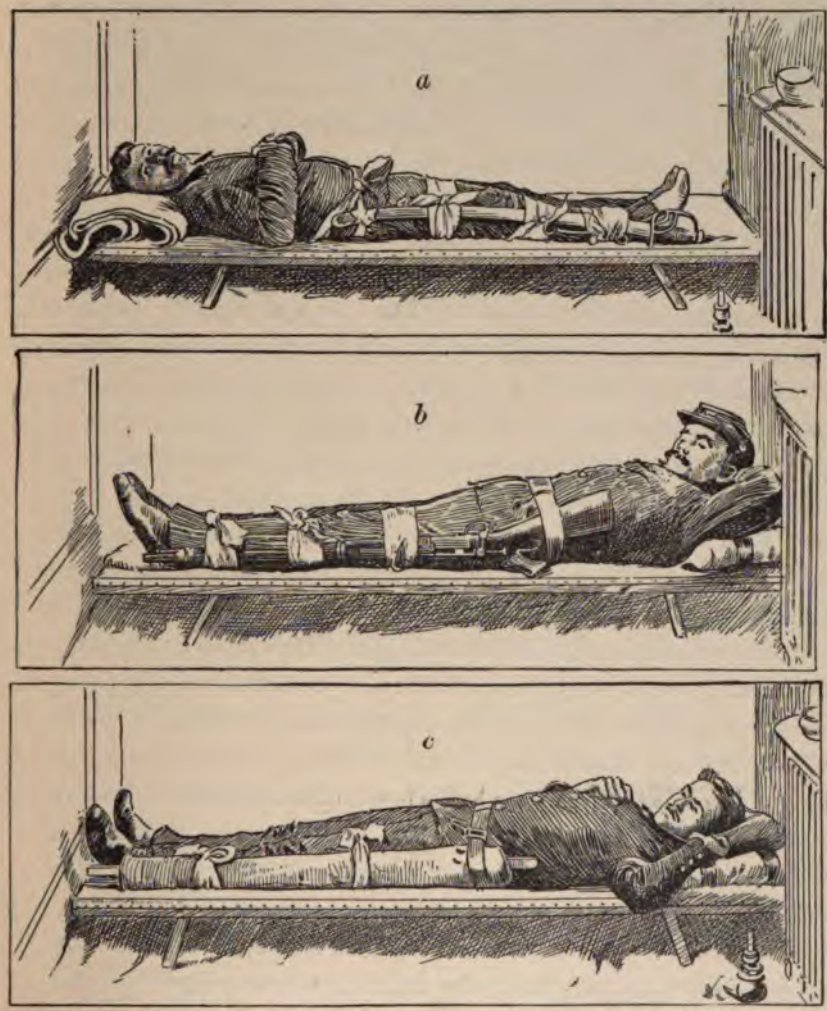


FIG. 84.—Use of weapons and military equipments as temporary splints (*Senn*).
a, sabre; *b*, musket; *c*, blanket and stick.

enumerate the many different materials that in cases of emergency may be used as splints. Wherever a wound may be received some agent that will serve a temporary purpose for immobilization will be found. In lieu of better, bundles of straw or twigs, or layers of folded newspapers,

may serve an excellent purpose as splints. Upon the battlefield various weapons admit of many most excellent applications as splints. In Figure 84 are seen illustrations of such improvised weapon-splints. Thin strips of wood, shaped according to the requirements of the part to which it is to be applied, and padded with cotton-wool, will always be found to make most excellent splints. There are two kinds of material, however, which from their special advantages as agents of immobilization in the treatment of wounds deserve more extended notice. These are wire-gauze and plaster-of-Paris.

Wire-gauze.—This material is made of wire from one-twentieth to one-tenth of an inch in diameter, woven into a fabric, the meshes of which are from three-tenths to five-tenths of an inch square, or the length of the mesh may be greater than the width. After the gauze is cleaned with acid, it is put into melted zinc, which covers the wires and fastens them quite firmly together where they cross each other, making a firm and strong structure. The material is a common article of commerce, is cheap, is to be found in all hardware shops, and is put to many economic uses. My attention was first called to the value of this material for surgical purposes in 1873 when I entered upon duty as adjunct surgeon to the Long Island College Hospital, where it had been introduced by my immediate predecessor, Prof. J. S. Wight. Its surgical uses have been described by Prof. Wight,[1] as follows: In the first place, the fabric can be cut into any desired shape by a pair of tinsmith's shears. The separate wires may be cut out by a pair of cutting pliers. The pieces of gauze may be bent into any required form by the hands of the surgeon; and when bent it will generally have enough firmness and resistance to keep its form under all ordinary circumstances. It is very light—having the same extent of surface, it is lighter than wood, tin, zinc, or binder's board, used for splints. It ventilates the part to which it is applied better than any other splint material. It is very desirable where irrigation is needed; it is non-absorbent. At any time it can be removed, disinfected, and reapplied with facility. It may be strengthened by fastening to it by small staples light strips of wood. It may be used to strengthen plaster-of-Paris

[1] The Surgical Uses of Wire-cloth. Proceedings of the Medical Society of the County of Kings, January, 1881, p. 375.

splints, particularly when they are to be fenestrated. The combination of qualities which have been enumerated—its cheapness, the readiness with which it can be shaped and moulded to a part, its lightness, its non-absorbent qualities, and the perfect freedom with which its open-meshed interstices permit the passage of moisture through it, and the facility with which it can be sterilized by boiling—make it a material of great value for purposes of wound-dressings.

Plaster-of-Paris.—Of the various substances that have been used while in a moist and pliant condition to envelop a part, a firm mould of which they afterward form by hardening, plaster-of-Paris has proved to possess in the greatest degree the qualities needed for common use. It is generally easily and quickly procurable; it is cheap; its manipulation is simple; it quickly hardens and forms a firm and accurate envelope of the part to which it is applied, so as to insure absolute immobility and uniform compression with perfect comfort. It is porous, and so does not prevent the escape of the natural perspiration from the parts covered by it. Fine white plaster (dentist's plaster) that has recently been calcined is to be chosen for use in making an immobilizing apparatus. If it has been exposed to moist air, it will have absorbed sufficient moisture to prevent its hardening readily and firmly. If fresh plaster is not attainable, the old may be made again fit to use by reheating it. For this purpose it will simply be necessary to heat it in an iron pan over a good fire for half an hour, or until it ceases to "bubble."

The part to be immobilized should be wrapped with a layer of cotton-wool—sheet wadding—or in default of this, by strips cut from a woollen blanket. A stout thread, or bit of cotton twine, wound loosely in a rapid spiral over this preliminary layer of cotton or blanket, will be convenient in keeping them in place while the plaster is being applied.

Three different methods may be used in applying the plaster.

One method is to cut strips of coarse blanket flannel, crash towelling, or similar strong, open-meshed material, into suitable lengths and shapes, so that they will partially envelope the part like a cuirass, as in Figures 87 and 88, and dip them into plaster-of-Paris when mixed with water, so as to have the consistency of a rather thick cream. The cloth strips thus impregnated are then applied to the limb, and while the plaster is still plastic are secured to the limb by roller-bandages. As many layers may

be applied as may be thought necessary to give the requisite strength to the splint. The Bavarian splint (Figures 85 and 86) is made by fastening two pieces of such cloth together by a row of stitching down the centre, and pouring the plaster-cream between the pieces.

When it is to be employed the layers of cloth should be applied to the limb so that the row of stitching is at the nether side of the limb; then

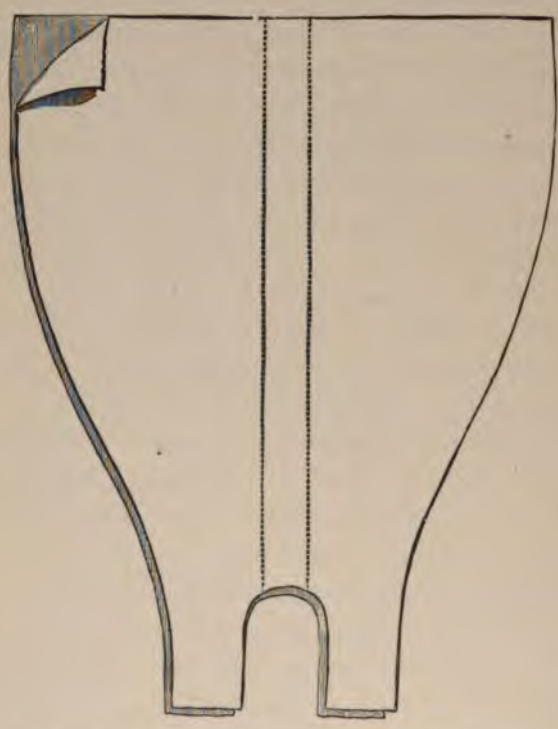


FIG. 85.—Pieces of cloth as shaped for applying the Bavarian splint to the leg (*Esmarch*).

FIG. 86.—The Bavarian splint applied.

tne innermost layer is brought up about the limb and smoothly adapted to it, its edges, meeting in front, being secured with pins temporarily. Then the plaster is poured thickly over the outer surface of this layer, and upon the inner surface of the outer layer, being uniformly spread over them by the hand of the surgeon. The outer layer is then to be brought up to the first, and after having been properly moulded to the

limb by the hand, is confined by a roller-bandage until the plaster has hardened.

It will then be found that there has been made a splint consisting of two lateral halves, connected together behind by a cloth hinge, which permits the two halves of the splint to open like a book and expose the injured parts. When anterior and posterior strips (Figure 87) are used, there results two accurately fitting shells (Figure 86), either one of which can be lifted off to facilitate inspection of the part, while it is still supported by the other. A great variety of forms of splints, as needed for special locations and injuries, can be made from strips of cloth and plaster after this method.

FIG. 87.—Shape of anterior and posterior flannel strips, for application to lower limb from midthigh to toes (*MacCormac*).

The following practical directions for the preparation of these splints are by MacCormac ("Antiseptic Surgery," p. 188), and are worth heeding: "Dressers seldom know the best way to prepare plaster-of-Paris for use. It is often made too thick, and sets too soon; or, it is too thin, and additional plaster is added at the last moment, which makes the mixture lumpy and unmanageable. A sufficient quantity of water for the purpose in hand should be first poured into a basin, and then the plaster lightly shaken into it, handful after handful, or spoonful by spoonful, but without stirring, until the plaster just begins to float on the surface of the water; then enough of plaster has been added, and, on stirring, it will quickly blend with the water, and a homogeneous mixture, of the proper consistence, that of thick cream, will be the constant result.

"In this the flannel strips are dipped, and they will take the mixture better, and form a stronger and more durable splint if they have been previously wetted, all superfluous water being wrung out."

The second and more commonly used method consists in the application of roller-bandages whose fabric is saturated with the plaster. These

bandages are previously prepared by rubbing into their interstices the dry plaster; when required for use, the bandages, made into loose rollers, are immersed in warm water for a short time, until bubbles of air cease to escape, when they are at once applied. To reinforce the bandages, plaster-cream can be smeared over them after they have been applied. Ordinary muslin rollers are not well adapted for use as plaster bandages. A more open-meshed and absorbent fabric is needed.

The impregnation of the meshes of the cloth with the plaster with the hand or knife produces an imperfect and uneven result, while it is at the same time a dirty and disagreeable process. The following simple method affords a more satisfactory result in a most convenient manner. It is to put the end of the bandage through a slit near the bottom of one end of a small box, carry it through the box along its bottom and out at a similar slit at the other end of the box; fill the box with plaster; by drawing on the protruding end of the bandage, rolling it up as it comes out, its meshes will be fully laden with the plaster through which it has been drawn on its course through the box, the excess of which will have been scraped away by the edges of the slit.

FIG. 88.—Anterior leg splint.

The third method consists in applying bandages of open-meshed fabric, as gauze or mosquito-netting, to the limb, and then smearing them with the plaster-cream, adding successive layers of the bandage and of the plaster until a sufficiently strong splint is built up. A very light, firm and tough splint can thus be built up.

Where there are open wounds, openings must be made in the splint by which ready access to the wound can be secured and free escape of the secretions may take place (Figure 90). These are best made as soon as the plaster has hardened sufficiently to be cut without displacement or crumbling. The material can then be cut quite easily with a strong, sharp knife. The edges of the fenestrum and the adjacent surfaces of the splint can be readily made impermeable to any secretions that may come in contact with them by brushing them over with melted paraffine. When the size of the opening required for the necessary exposure of the wound is so great that a connecting isthmus of sufficient strength is not left, the

splint may be made in different sections, and the two sections connected together by metal or wooden bars (Figure 91), or the isthmus may be retained and reinforced by metal bars as in Figure 89.

Plaster-of-Paris may often be combined to excellent purpose with other materials, as wood, metal strips or wire, or wire gauze, in the construction of splints for special purposes. One of the merits of plaster-of-Paris splints, as well as of plastic splints in general, is the readiness with which they are suspended, and thus facilitate the movements of the patient without endangering disturbance of the wound to the degree that is unavoidable when the wounded member lies on an immovable surface. The limb, after having been encased in the splint, should be swung by pieces of rubber tubing or bands, passed around it at suitable distances from each other and tied to a bar above (Figure 92).

FIG. 89.—Plaster case fenestrated and reinforced by lateral steel bars.

The removal of a plaster bandage may be accomplished best by using a suitable saw for dividing it. A large-sized Hey's saw makes a very convenient instrument to be used for this purpose. It is necessary that the teeth should be widely set, so that a wide groove may be cut in the bandage for the free passage of the saw. A powerful pair of shears, with one blade flattened so as to be insinuated beneath the splint, will suffice to slit up many splints. Figure 93 shows the original model of Seutin, which has not since been improved upon. In the absence of special instruments for cutting plaster splints, they may be readily cut with an ordinary stout pocket-knife or potato-knife by first saturating the line of cutting with common table vinegar. The effect is to soften the hard board-like plaster mass so that it is easily cut.

Subsequent Dressings.—Too early and too frequent interference with a wound may become an obstacle to the highest degree of success in securing its undisturbed healing. Infrequent dressing is eminently con-

Fig. 90.—Windowed plaster-of-Paris bandage (*Esmarch*).

ducive to that absolute rest which is to be kept in view, whatever method of treatment is adopted. When the first dressing of the wound has been

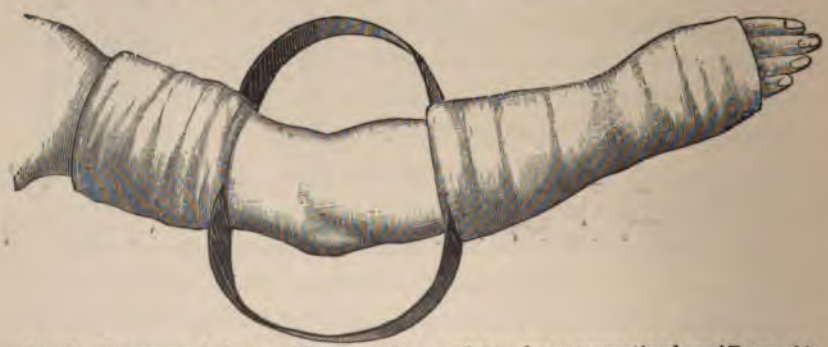


Fig. 91.—Interrupted plaster-of-Paris bandage, with iron hoop connecting bars (*Esmarch*).

conducted in accordance with the principles of rational wound-treatment which have been described; when the bleeding has been carefully and permanently arrested, the wound-surfaces and recesses perfectly cleansed

and preserved from infection, or rendered aseptic, the retention of secretions and débris provided against by efficient means of drainage, the divided surfaces brought together as far as possible and retained in apposition, and adequate means of protection against septic infection, mechanical injury, and motion, whether passive or active, has been provided, its rapid and undisturbed healing will certainly take place, with but few changes of dressings necessitated, except in those rarely occurring in-

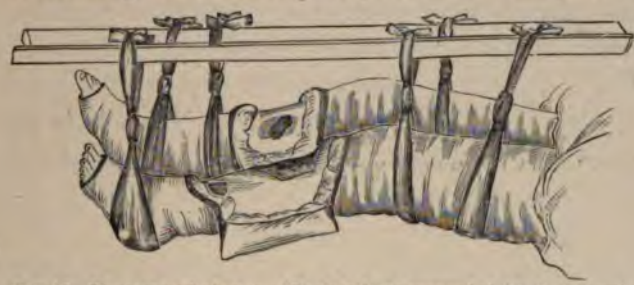


FIG. 92.—Fenestrated plaster-of-Paris splints suspended (*J. D. Bryant*).

stances in which the general condition of the patient prevents a supply to the region of material proper to repair. The after-cares from the surgeon will be limited to a watchful oversight of the means of protection and immobilization, of drainage and apposition, that have been employed, that they be removed, substituted, or reinforced by others as soon as they are no longer called for, or have become inefficient. The course of the wound in its repair is largely dependent upon the perfection which each

FIG. 93.—Seutin's plaster shears.

one of the great indications for treatment which have been dwelt upon may have been met at the first. It has been seen that the most frequent cause of wound-disturbance, as well as the cause of the most perilous of the disturbances that may complicate wounds, is the conjunction of the agents and the subjects of bacterial activity. The prevention of access of the one, and the removal, as fast as formed, of the other, therefore constitute the two great commandments of the law of wound-repair, each of which, equally, every one who undertakes to treat a wound must comply

with to the best of his ability, if he would acquit himself of reproach for the results of disturbance that may supervene in the progress of the wound. Inflammatory, erysipelatous, gangrenous, or septicæmic complications attacking wounds are not to be regarded as unfortunate and unavoidable accidents, but must be regarded as the results of errors or failures in the treatment which the wounds have received. It is especially in the treatment of fresh wounds, or the wounds made in the course of premeditated surgical procedures, that this responsibility of the surgeon is unavoidable. When a neglected wound, or one already manifestly septic, comes under the care of the surgeon, his responsibility is less than in the case of fresh wounds, but his duty still is manifestly to persistently endeavor to convert the dangerous septic wound into one that is aseptic, even if the trial be made in vain.

When the first dressing of a wound has been successfully and perfectly accomplished, it may not need to be disturbed for some days; in some cases, as has been mentioned in connection with special methods of protective dressing, ten and fourteen days may be permitted to pass without removing the dressings, by which time the wound may be found to be quite or nearly healed. In all cases where the wounds have been closed without drains, as long as the wound remains free from pain, and there is no acceleration of the pulse nor elevation of the temperature, the dressings may remain undisturbed. The use of the thermometer as a guide to the surgeon is an invaluable aid, a rise of temperature being a sign that should invite immediate examination of the wound for the beginnings of possible disturbances there, although it may also be occasioned by intercurrent troubles in other parts or organs of the body.

It is impossible to fix arbitrarily the periods for the renewal of the dressings. Each case must be a law to itself, according as the special conditions which it may present may determine. The indications which the drainage, the sutures, the compresses, the protective appliances may present have been sufficiently set forth, as to the principles that govern their use, in the various sections already devoted to their consideration.

In the changing of the dressings, and indeed in all the manipulations required about the wound, the utmost gentleness should be used, coupled with a deliberate speed that is possible only when nothing is done without a purpose, and every preparation for accomplishing that purpose has been

made beforehand. When splints are applied for purposes of immobilization, they should be so applied that they shall not interfere with the removal of the immediate dressings of the wound when necessary, in order that no necessity may arise for the premature removal of the splints.

ANODYNES.

The various preparations of opium, by the relief of pain, and the feeling of general well-being and comfort that they create, by their tendency to quiet muscular spasm, and to steady the heart's action, may contribute in an important degree toward securing the desired rest for a wound. They should be given in small and often-repeated doses, according as pain, restlessness, irritable pulse, or muscular twitching may demand for their control. When an anæsthetic has been given, as in surgical operations, the administration of an opiate by suppository introduced into the rectum, or hypodermically, should be made while the patient is yet under the influence of the anæsthetic.

CHAPTER XIII.

THE RELIEF OF DISTURBANCES OF HEALING—INFLAMMATION—GANGRENE—ERYSIPELAS—SEPTICÆMIA.

Treatment of Inflammation—Opening the Wound—Incisions—Removal of Foreign Bodies—Position—Compression—Reduction of Heat—Cold Compresses—Evaporating Lotions—Irrigation—Immersion—Ice-bags—Cold Water Coils—*Relaxation of Vessels—Abstraction of Blood—Interrupting the Blood-supply—Résumé—Treatment of Gangrene*—Incisions—Continuous Antiseptic Irrigation—Stimulants—*Treatment of Erysipelas*—Antiseptics—Subcutaneous Injections of Carbolic Acid—Superficial Applications—Tonics and Stimulants—Antiphlogistics—*Treatment of Septicæmia*—Local Disinfection—General Treatment.

INFLAMMATION.

THE treatment of an inflamed wound must be directed both to the removal of the cause of the inflammation and to the relief or mitigation of the conditions that attend it, or result from it. The substitution of destructive inflammation for the constructive processes that make for the repair of a wound never takes place, except as the consequences of defects either of wound-cleanliness, or of wound-protection, or, more frequently, of both, hence the first duty of the surgeon, when in the presence of an inflamed wound, is to seek for its causes and to address himself first to their removal.

With but few exceptions an inflamed wound is a septic wound, and the cause of the inflammation is the irritation of the products of bacterial multiplication in retained secretions. It is, accordingly, those wounds in which the retention of secretions is most difficult to prevent, as in wounds of joints and other cavities, wounds leading down to fractured bones, and deep, irregular-punctured wounds, that severe inflammation is most frequently met with.

To give free vent, therefore, to all wound-secretions that may have been retained is the first thing to be attended to in the treatment of such a wound. This may require nothing more than the cutting of a stitch, so

that the natural gaping of the wound may suffice for the required vent, or it may require counter-incisions and the use of drains.

Whatever means the special conditions of the parts may make necessary should be thoroughly and systematically employed until ample provision for the entire flowing away of the secretions as fast as formed has been secured. A spreading and diffuse inflammation indicates the presence of active micro-organisms of intense virulence, together with, in most cases, a low degree of vital resisting power in the region infected. The retention and diffusion among such tissues of the poisonous products of the bacterial activity should be prevented at the earliest possible moment by free incisions into the full depth of the infected region. When timely and sufficiently ample openings have been provided, the destructive process is in most instances arrested at once.

Mechanical irritation, motion, and premature use of a wounded part may provoke inflammation by preventing or breaking down adhesions, inflicting mechanical violence upon tender tissues, interfering with repair, and thus presenting anew the conditions in which septic changes may become rife. The search for and removal of foreign substances that may have been left in a wound, as splinters of wood, pieces of glass, rusty nails, bits of clothing, detached pieces of bone, etc., must not be overlooked in cases where their possible presence may be the cause of the inflammation.

When the causes of the inflammation have been removed, perfect rest of the part in its further care should be sought for. The part must be placed in an elevated and comfortable position, and must be immobilized. In addition may be used such other means to relieve or mitigate the pain, heat, and swelling of the part, and to overcome the vascular congestion upon which they depend, as the conditions of the wound and the judgment of the surgeon may indicate as needful and practicable, although in most cases as soon as the fountain of sepsis has been abolished, the spontaneous return of the part to a condition of satisfactory repair is rapid without other special so-called antiphlogistic measures. The accessory means available act either by compressing the swollen tissues, reducing the heat, relaxing the vessels, abstracting blood, or interrupting the blood-supply.

Compression.—The practice of compression with immobilization is

attended with the most marked advantage in hastening the absorption of inflammatory products. All that has been said with reference to their use as protective measures to healing wounds applies with yet more force to an inflamed wound. The compression must be even and continuous, and must be so applied as to avoid any constriction. Pain and strangulation, with gangrene, may result from attempts at circular compression in which every part from its distal extremity upward is not equally compressed. Properly applied compression is attended with comfort, and whenever it produces discomfort the means of compression should be rearranged or removed altogether. An elastic roller-bandage of pure rubber (Martin's bandage) can be used to make compression with very great advantage, and may be adapted to every region of the body. Rollers of soft cotton cloth, or of flannel, with layers of cotton-wool, enveloping the inflamed part, may be used for making pressure. Compressed sponge, confined by a bandage, and then supplied with water, may be made the agent of strong and elastic pressure by its tendency to swell. Bags of water, or of other substances that will permit an even adaptation of their surface to that of the inflamed part, may be laid upon inflamed parts so as to exert uniform compression.

THE REDUCTION OF HEAT.—The judicious use of cold, locally applied, is of especial value in antagonizing the tendency to the excessive active hyperæmia which marks the earlier phases of inflammatory action. It abstracts heat, constringes the vessels, acts as a local sedative, and tends to inhibit the activity of bacteria. Its power to diminish vascular excitement may be pushed to such an extreme that deficient nutrition of the parts to which it is applied may be produced, and deficient repair, even local death, result. Its use should be confined, therefore, to the control of acute inflammatory conditions, or as an application to wounded parts in which inflammation is both prone to occur and to be followed by disastrous consequences, as in wounds of joints and of the head. Cold should be so applied as to maintain a continuously uniform low temperature, for when applied intermittently each application is followed by more or less vascular reaction which disturbs the repair of the wound.

Cold Compresses.—Cold may be applied by enveloping the part in compresses wrung out in cold water, the compresses being frequently changed before they have become warmed. This is apt to disturb the

injured part, and is likely to be neglected, so that it is an unreliable and objectionable method, though the one most frequently adopted.

Evaporating Lotions.—Compresses may also be wetted with a dilute alcoholic lotion, the rapid evaporation of the spirit sufficing to cool the parts. Lotions containing a mixture of equal parts of ammonium chloride (sal ammoniac) and potassium nitrate (saltpetre) lower in a marked degree the temperature of parts to which they are applied. A strength of half an ounce of each salt to the quart of water is the proportion most frequently used.

Irrigation. — Continuous cold may be applied to a part by arranging a vessel of cool water above it so that a constant dripping of the water upon it may be secured (Figures 94 and 95). The part should first be covered by a piece of cloth large enough to extend upon the integument several inches beyond the wound, upon which the water from the irrigator shall fall and then be diffused. The evaporation of the water from the compress is quite rapid, and increases greatly the cooling effect of the irrigation, so that it is not necessary to employ water of a very low temperature. The water as it runs away should be caught upon an inclined plane (Figure 94), or upon some waterproof material beneath the limb (Figure 95) and guided into a receptacle below. The needful apparatus for irrigation may be extemporized from very simple materials. A common wooden

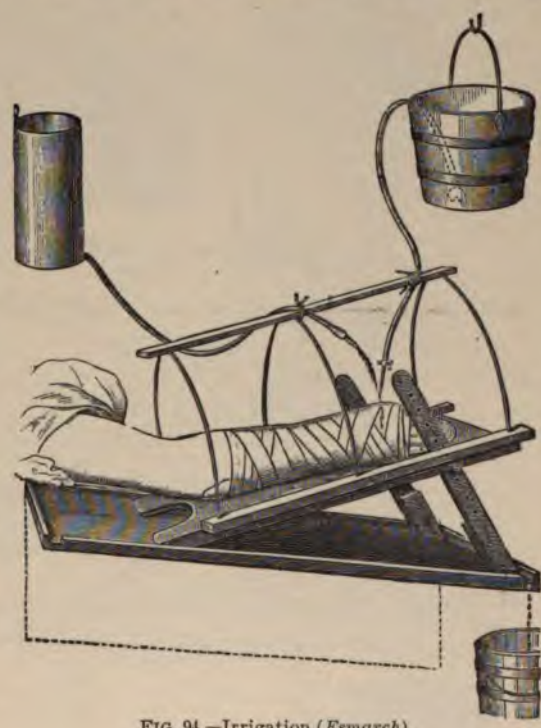


FIG. 94.—Irrigation (*Esmarch*).

or tin pail, a bottle with the bottom knocked out, an empty fruit-can, a wash-basin, a cup, anything that will hold water, and any material that will absorb or convey water suffices. Continuous irrigation of the recesses of a wound after suitable drainage tubes have been placed may be secured by connecting the tube from an irrigator with one end of the drainage tube. The water may be conveyed by making a siphon of a bit

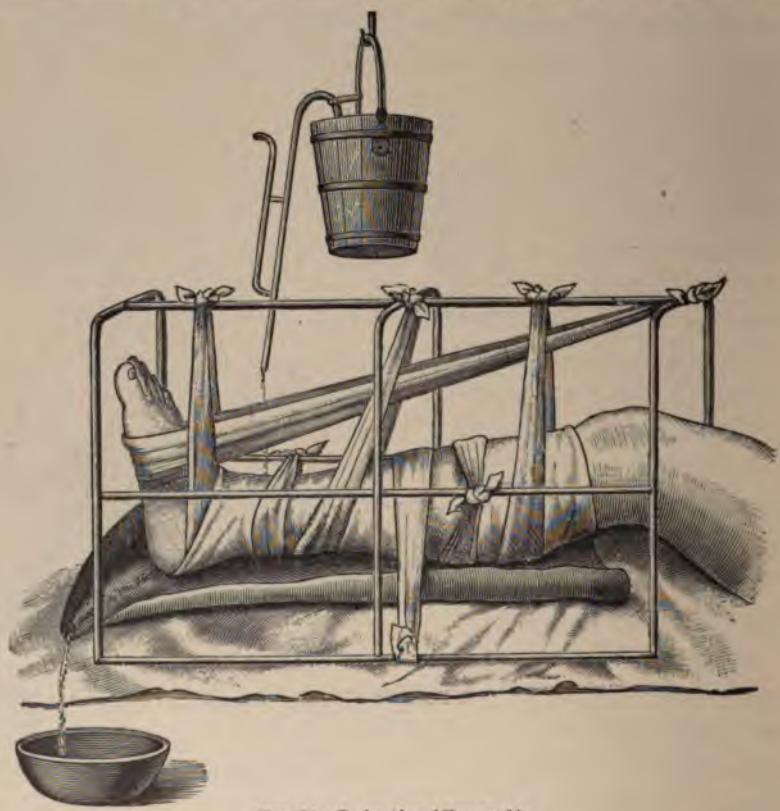


FIG. 95.—Irrigation (*Esmarch*).

of rubber tubing (Figure 94), or glass tubing (Figure 95), or out of a piece of candle-wicking or similar absorbent fabric. Tubes may be inserted into the bottom of the vessel containing the water, and the amount of the flow regulated by the use of suitable plugs in these outlet tubes.

Immersion.—Wounds of the extremities may be immersed in cold water, suitable vessels being provided in which the inflamed member may be laid. A very low temperature is not needed for producing energetic

reduction of temperature. The frequent addition of cool water to keep the temperature of the bath down to the desired point will require watchful care.

FIG. 96.—Rubber ice-bag.

FIG. 97.—Rubber cold-water coil for head.

Ice-bags.—Rubber bags (Figure 96), or, when they are not accessible, bladders, may be partly filled with pounded ice and laid upon a part. This method is particularly convenient for the application of cold to the head and to the joints. If the direct application of the ice-bag is too cold, layers of cloth may be laid between the ice-bag and the part. An ice-bag may be securely closed by wrapping its closed mouth about a wooden disc or large cork and tying it by a tape.

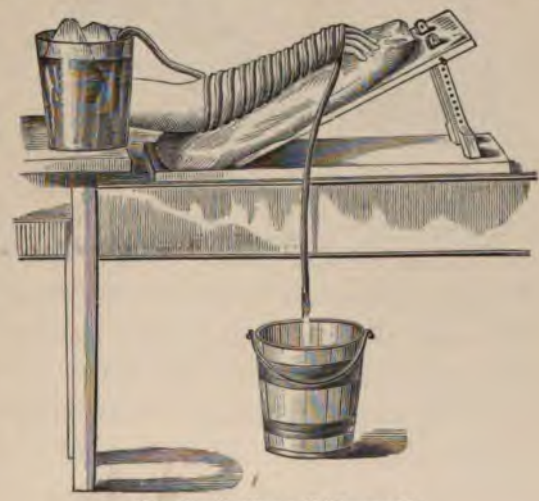


FIG. 98.—Cooling coil (*Esmarch*).

Cold Water Coils.—Cold may be continuously applied to any part of

the surface of the body by placing upon them mats formed of rubber tubing coiled to the requisite size and shape, the coils being secured by wire tape, and by passing, either by fountain or siphon action, a continuous current of cold water through the tubing from a reservoir placed at a convenient height. Similar mats may be made of soft metal (Leiter's tubes). The extremities may be encircled by spiral turns of tubing through which the water may flow. Figure 98, from Esmarch's "Handbook," shows a forearm thus encircled by a tube, one end of which is placed in a vessel filled with ice-water, while the other, hanging down, discharges the current into an empty pail. Figure 99 illustrates the application of the cold water coil to the penis. The coils of tubing are retained in place by a band of cotton or linen cloth.

FIG. 99.—Cooling coil (*Otis*).

THE RELAXATION OF VESSELS.—Warmth and moisture produce a soothing and relaxing effect upon an inflamed part directly opposite to that of cold. They promote dilatation of the vessels and thus relieve tension by enlarging the calibre of the vessels through which the blood is crowding. They favor exudation and thus relieve the congested vessels. They relieve pain and thus diminish the effect of reflex irritation. They favor, however, bacterial activity, and for this reason have only a limited use in the treatment of surgical inflammation. Moist heat may be applied by compresses wrung out in hot water—fomentations—by poultices and by immersion in hot water. The compresses and the poultices should be covered over by a layer of impermeable material, as oiled silk or rubber tissue, to retain the heat and moisture and lessen the frequency with which the application requires renewal. For poultices any substance capable of being reduced to a soft mushy consistence with hot water may

be employed, but on account of the general facility of its management and the length of time that it retains its heat and moisture, ground flaxseed is to be preferred. Poultices should not be made so thick as to be burdensome by their weight, nor should they remain unchanged for a longer period than six hours. Immersion in hot water is the most beneficial method of procuring vascular relaxation, and is to be chosen whenever practicable. It may contribute likewise to drainage and to wound-cleanliness.

THE ABSTRACTION OF BLOOD.—Local bleeding may have a very beneficial effect upon an inflammation by the relief of tension which it produces upon the congested tissues and the over-distended vessels. It may be obtained by scarifications, by incisions, by scarifications and cups, and by leeches. The bleeding which may attend the incisions required for the more free drainage, and for the relief of tension in inflamed parts, is of value in immediately relieving the congestion caused by previous conditions.

THE INTERRUPTION OF THE BLOOD-SUPPLY.—The attempt to diminish the amount of blood supplied to an inflamed part is a logical result of the recognition of the fact that the active afflux and undue retention of blood in the part is the most prominent factor in the distress and damage which an inflamed part suffers. Against this active hyperæmia most of the remedial measures which have been used, other than free incision and drainage of septic matters, have been directed. Position, compression, cold, and blood-letting have been seen to be of benefit either by preventing the blood from going into a part, or by removing it from it. This may be yet more effectually accomplished by cutting off the main stream of blood from the engorged tissues, by which device the veins are left of their original calibre to drain away the superabundant blood, while the volume and force of the arterial current are greatly diminished. As the result, the over-distended capillaries soon recover their normal calibre, and the ordinary processes of nutrition and repair are re-established. Interruption of the blood-supply may be accomplished by the various means which have been discussed in connection with the arrest of hæmorrhage (Chapter VII.), viz.: forced flexion, compression of the main artery by means of the finger, tourniquet or a weight, acupressure, and ligation.

Forced flexion is particularly applicable to the treatment of inflamed

wounds of the forearm and hand, and is easily and well combined with the means of elevation, compression, and immobilization.

RESUME.—The various resources which have been mentioned for antagonizing and mitigating traumatic inflammation are sanctioned by the practice of the past and by the authority of surgical teachers; but the more accurate knowledge of the present with reference to the essential causes of inflammatory disturbances of wounds must relegate them to a less important place, while the greatest importance must attach to those measures which may rid a wound of the agents and subjects of sepsis. Free incisions for the relief of tension and the escape of débris, adequate drainage, cleanliness in the aseptic sense of the term, with proper protection and perfect rest, afford the surest and speediest means of overcoming inflammation, since they remove its causes, carry away its products, and favor in the highest degree the natural nutritive processes of the part, by means of which recovery from damage already sustained is to be secured, and repair of the original injury is to be accomplished.

GANGRENE.

The appearance of spreading gangrene in a wound calls for immediate energetic antiseptic treatment to destroy the micro-organisms, the caustic products of whose vital activity, as they successively invade new tissues, produces the gangrenous phenomena. All necrosed tissue should be removed at once with knife and scissors, and the living tissues exposed should be freely and thoroughly cauterized by the eight per cent. chloride of zinc solution, which should be injected into every recess and irregularity of the wound. The swollen and infiltrated tissues leading from the gangrenous focus, particularly the intermuscular interstices and the subcutaneous connective tissue, should be opened by numerous small incisions through the integument to permit the escape of secretions and of débris and to enable the disinfecting fluid to be introduced into as many places as possible. Longer incisions and counter-incisions may be made as shall be required for the relief of tension and for the freest imaginable drainage. When gangrene has attacked a wound, the wound must be kept exposed, so that its condition may be under continuous observation while the means of powerful and permanent disinfection are being em-

ployed. An open method of treatment with continuous antiseptic irrigation offers a most effective means which will overcome the most serious cases of sepsis when all other precautions have been found insufficient. The adjacent integument should be frequently anointed with vaseline to protect it from the macerating influence of the irrigation.

As an irrigating fluid, a one per cent. solution of carbolic acid, or a 1:1000 solution of corrosive sublimate, is adequate, or in case of need for prolonged continuous irrigation, a one-half of one per cent. solution of acetate of alumina, the use of which is not liable to provoke eczema or intoxication. The antiseptic irrigation should be continued until the wound is rendered perfectly aseptic. Iodoform dressings then will be particularly applicable as protective and absorbent dressings.

The general strength of the patient must be kept up by the liberal use of alcoholic stimulants, by nutritious food, by tonics, and by anodynes.

ERYSIPELAS.

When the repair of a wound becomes disturbed by erysipelas, the patient should at once be isolated. A surgeon or attendant should not pass from the care of an erysipelatous case to that of a healthy wound until after the most thorough antiseptic precautions for securing cleanliness have been observed. These remarks apply equally to cases of gangrene. The appearance of erysipelas is always due to some defect or neglect in the antiseptic precautions, whereby infection with streptococci has been introduced. Care to prevent bacterial infection in wounds is the one efficient safeguard against its appearance. By the adoption of antiseptic methods of wound-treatment as a matter of routine, it has resulted that erysipelas, from being one of the most common, has become one of the most rare complications of wound-healing.

The first thing to be recognized, therefore, upon the appearance of erysipelas in a wound is that it is of specific septic origin, and that it most especially calls for those methods of treatment which are adapted to septic wounds.

Treatment may be directed for the purpose of either:

1. Destroying or rendering inert the specific micrococcus. *Antiseptics.*

2. Increasing the resisting powers of the invaded tissues. *Tonics and stimulants.*

3. Alleviating the local inflammation and removing its products. *Antiphlogistics.*

ANTISEPTICS.—The power of antiseptic substances is more readily exercised as a preventive means than as a curative resource. The infiltration of the tissues with the micro-organisms tends to render them inaccessible to antiseptic applications, unless these be of sufficient strength to destroy the tissues as well. The streptococci, according to Fehleisen, spread along the lymphatics only, but their dissemination takes place not only along the course of the lymph stream, but in all directions, without reference to the direction of the lymph current.

Subcutaneous Injections.—Hueter,[1] in 1875, recommended the early subcutaneous injections of dilute watery solution of carbolic acid. Hypodermic injections of salicylic acid have also been used with success.

The use of subcutaneous injections of antiseptic solutions to abort attacks of erysipelas has been found to be most certainly successful when employed at the onset of an attack; later, when the infiltration of the pathogenic organisms and the inflammatory reaction has attained a greater extent, it becomes less probable that the antidote can be injected so as to come in contact with the noxious organisms in sufficient quantity and to the necessary extent. Differences in the stage of the disease at which these injections are practised, and in the manner in which the injection is performed, will explain much of the differences in the results obtained by different surgeons.

The antiseptic to be used must be one that is not too irritating, that is diffusible, and that will not coagulate the tissues among which it is introduced. Carbolic acid, in dilute watery solution, answers these indications better than any other agent of equal antiseptic power. Carbolic acid was the antiseptic used by Hueter. The method of its use finally settled upon by him[2] was to inject three to five hypodermic syringefuls of a three per cent. watery solution of the acid, at numerous points, into the healthy subcutaneous tissues along the borders of the erysipelatous

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[1] *Deutsche Zeitschrift für Chirurgie*, 1875, 4 Bd., Heft 5 and 6.

[2] Schüller. *Jahresbericht. Deutsche Zeitschrift für Chirurgie*, 1878.

patch. These injections demand repetition once or twice, according to the intensity of the inflammation and its tendency to extend. Even three or four repetitions may be needed before the erysipelas will cease to advance. In but few cases will this method of treatment fail to greatly circumscribe the disease.

Superficial Applications.—The application of antiseptic substances to the surface of the skin in many cases is of benefit, but the results are comparatively uncertain and weak. Tincture of iodine, tincture of the chloride of iron, tar, strong solutions of nitrate of silver, of sulphate of iron, of salicylate of sodium, of carbolic acid, and other agents, have been used by various surgeons, and in turn have been esteemed as of value and as inefficient. A twenty-five per cent. ointment of ichthyol, or a twenty per cent. ointment of naphthalin, thoroughly smeared over the affected surfaces, will cause the unpleasant subjective symptoms of erysipelas to disappear rapidly, followed by a more slow subsidence of the swelling or œdema. Usually its application beyond the limits of the disease will check its further spread, or at least mitigate it.

Tonics and Stimulants.—The general depression and febrile reaction which attend attacks of erysipelas are themselves the results of septic infection by absorption of the products of the local disease. With the subsidence of the local disease, the general symptoms also disappear, and yet by reason of the general depression of the natural resisting power of the body which they produce, they may contribute to the greater severity and the prolongation of the local trouble. Those general remedies, therefore, will be of value which shall either contribute to general nutrition, or shall act as stimulants and roborants. Tincture of the chloride of iron, quinine, and opium are of great value in many cases. A supporting diet is of importance. The use of proper means to keep the digestive and excretive apparatus in active condition must be resorted to.

Antiphlogistics.—Since the local inflammatory phenomena which mark erysipelas constitute its most obvious symptoms, the mitigation of these phenomena constitute a very important part of the treatment called for. The treatment of the inflammation is to be conducted on the same principles and by the same methods which have been discussed in the first part of this chapter. When the inflammation is limited to the skin only, those applications which will soothe and protect it find use. A layer of

absorbent material kept saturated with a lotion of lead and opium (liquor. plumbi subacetatis, ℥j.; tinct. opii, ℥ss.; aquæ fervent., Oj.) is an excellent application; or the skin may be dusted with finely powdered starch, lycopodium, or subcarbonate of bismuth, and covered by a layer of cotton-wool; or it may be anointed with oil or vaseline, either pure, or containing some antiseptic, or sedative, or astringent substance.

When the deeper structures are involved in the inflammation—phlegmonous erysipelas—all the resources of art for the control and relief of sepsis and of inflammation become drawn upon. Position, rest, cold, heat, immersion, antiseptic irrigation, multiple incisions, drainage, compression, depletion, are to be used, each in accordance with the indications and methods already laid down for combating inflammation in general.

SEPTICÆMIA.

Septicæmia is a generic term that includes every grade of general septic infection produced by the absorption of septic wound-products, from a slight febrile reaction to the cases of more intense blood-deterioration with the formation of diffused secondary suppurating and septic foci (Pyæmia).

Local Treatment.—All that has been said as to the treatment of local septic disturbances applies with equal force to the treatment of general blood-infection, for where further new supplies from local septic foci are arrested, the return of the blood to its normal state, by the elimination and destruction of the septic matters already mingled with the circulating fluids, begins at once to be manifest. Local disinfection, therefore, is the first and most important matter to be accomplished in the treatment of traumatic septicæmia. In the occasional cases of rapidly developing and profound prostration attended with generalized bacterial growth throughout the blood-mass, with an insignificant local wound, as in cases of dissection wounds or in infected wounds in diabetics, and in some cases of streptococcic puerperal infection, whatever may be done to the wound will have little avail. It has been simply the portal through which the infection has entered, and has ceased to become of importance in comparison with the genuine general septicæmia which has resulted. In such cases, while autopsy reveals little gross changes in any viscus, the

blood has lost its coagulability and contains innumerable streptococci. A speedily fatal result is unavoidable in many instances; in others, with less intensity of original infection, or with greater resisting power of the blood, the continued multiplication of the organisms in the blood-mass is arrested, and a localization of infection in various organs follows; the capillaries of such foci become plugged with streptococci and the walls of the larger vessels and the lymph spaces are infiltrated with them. The infected tissues die, abscesses form, and each point becomes a fountain of ptomaine products to further poison the blood-mass. Such secondary abscesses, whenever they are accessible, should be incised and treated upon the same principles as primary suppurating dépôts.

GENERAL TREATMENT.—The indications to be met by general treatment are to mitigate general symptoms, to favor elimination, to counteract prostration, and to relieve organic complications as they arise.

PART II.

SPECIAL WOUNDS.

SECTION I.

VARIETIES THAT MAY OCCUR IN ANY PART OF THE BODY.

CHAPTER XIV.

SUBCUTANEOUS WOUNDS—INCISED WOUNDS—CONTUSED WOUNDS—LACERATED WOUNDS.

Subcutaneous Hæmorrhage—Restriction and Absorption of Effusions—Massage—Dry Cupping—Sorbefacients—Inflammation—*Incised Wounds*—Rest—*Contused and Lacerated Wounds*—Peculiarities—Secondary Hæmorrhage—Primary Cleansing—Drainage—Necrosis of Tissue—Coaptation—Period of Granulation—*Contused Punctured Wounds*—Incisions.

SUBCUTANEOUS WOUNDS.

THE perfection of the protection which the unbroken skin affords to a subcutaneous wound simplifies very much the treatment which is demanded, while it at the same time diminishes very greatly the dangers to be apprehended of disturbances arising in the course of its healing. As subcutaneous wounds may be of every grade of severity, from a slight bruise to ruptures and lacerations of important organs, and the disorganization of extensive masses of tissue, the amount and character of the treatment which they must receive will greatly differ. Mere inspection may not be sufficient to reveal the amount of damage, the repair of which is to engage the assistance of the surgeon, nor may its full amount be recognizable until after some time, when its subsequent course shall have demonstrated more fully its extent by the degree of functional disturbance which results from it.

The most important indications of treatment presented by subcutaneous wounds are the control of hæmorrhage, the restriction and absorption of effusions, and the maintenance of the injured parts at rest until their continuity has been restored with tissue of sufficient firmness to again endure the functional activity of the part.

SUBCUTANEOUS HÆMORRHAGE.—The mutual pressure of the parts among which the bleeding point lies is usually sufficient to restrict within moderate limits subcutaneous hæmorrhage. This is still further aided by the irregularities of the rents in the vessels themselves, which tend to

entangle the fibrine of the blood, and to produce clot-plugs that may seal them up. Hæmorrhages into the great cavities of the body, however, having less restraint upon their flow, tend in many cases to speedy death. When large arteries are ruptured subcutaneously, it is necessary to freely expose the point of rupture by incision, and ligate upon both the proximal and the distal sides of the rupture. The further treatment of the wound is then removed from the category of subcutaneous wounds. The most frequent subcutaneous hæmorrhages are those which attend contusions and result from rupture of subcutaneous veins and capillaries, the amount of the extravasation depending upon the vascularity of the part and the severity of the contusion. The connective and muscular tissue interspaces become infiltrated with the effused blood, and even more or less distinctly bounded cavities containing blood may be formed. The discolorations produced from the wide diffusion of extravasated blood, by their extent, mark its degree, and persist for a long time.

Special treatment to control hæmorrhage of this character is rarely called for. When the continuance of hæmorrhage is evident, compression by means of an evenly applied bandage, with or without an intervening compress, will suffice for its control. The application of cold would also be an additional available resource.

Restriction and Absorption of Effusions.—The arrest of hæmorrhage is to be followed by the use of means to restrict the amount of active hyperæmia within the limits needed for repair. Cold lotions, evaporating lotions, or ice-bags, are of value as applications to overcome any tendency to excessive afflux, but the most valuable and powerful resource exists in immobilization and methodical compression after the methods described in Chapter XII. When material division of structure, as in the case of fractures of bones, or the rupture of muscles or tendons, has taken place, this immobilization, in a position that shall favor the apposition of the divided surfaces, must be continued until complete and firm reunion has been established.

The absorption of effusions is likewise promoted in a remarkable degree by compression. To this should be added, especially in the more severe cases of contusion and sprain, those means of preventing or overcoming the passive dilatation of the blood-vessels prone to remain after the first period of active hyperæmia, and of diffusing the effusion, and

thus promoting its absorption, which are found in methodically rubbing, kneading, percussing, and rolling the soft parts, with passive movements, which constitute "massage."

Massage may be used very early after an injury, within the first twenty-four hours. The skin over the affected part should be anointed with oil to protect it, for it is the deeper tissues that are particularly to be affected by the kneading. The thumbs and fingers are then to be applied with steady and firm pressure, their force being graduated according to the tenderness of the part, so as through the skin to rub, and knead, and roll the deeper tissues, diffusing the exudations present, stimulating the languid circulation, and exciting the absorbents. The manipulations should be begun beyond the margins of the tumefied and painful spots, which should be gradually approached. The soothing effect of the rubbing, when patiently and delicately applied, is such that soon pressure and movement over the points of chief injury are readily tolerated. By massage a more speedy relief from pain and swelling, and an earlier restoration of the function of the part can be secured in many cases than by any other method. It is particularly of value in the treatment of contusions, distortions and sprains of joints, and their sequelæ.

Dry Cupping.—The application of dry cups to the surface of the skin over the area of injury will powerfully assist in diffusing the effusions consequent upon contusions of the deeper parts, and will contribute to the comfort and the more speedy restoration of the function of the injured part.

Sorbefacients.—The use of various lotions for their presumed power in stimulating the absorption of effusions, though a popular and common resort, cannot, as a rule, be commended as of value. Their power to allay the violence of the primary afflux by their cooling or sedative properties is more marked. A traditional sorbefacient is a strong solution of chloride of ammonium with the addition of a small quantity of vinegar, applied upon folded flannel, covered with oiled silk, and renewed six or eight times in the twenty-four hours.

Douching a part with hot water, as hot as can be borne without suffering, continued for from twenty to thirty minutes, acts energetically in producing contraction of the dilated vessels and in restoring tone to the circulation and nutrition of an injured part, and in promoting absorption

of effusions. As an immediate application after a contusion or sprain, hot water, either in the form of a douche, bath, or by compresses, is preferable to cold applications by reason of the diminished tendency to passive congestion which follows its use. When the effused blood is collected in depôts, if its presence is a cause of discomfort or serious functional disturbance, it may be removed by aspiration, or through incision made in the overlying integument, provided adequate provision be used to prevent bacterial infection of the exposed cavity.

INFLAMMATION, complicating subcutaneous wounds, is to be treated in accordance with the general principles laid down elsewhere. When septic disturbances intervene, free incisions to evacuate septic matters must be made, and the general treatment already insisted upon for septic wounds followed.

INCISED WOUNDS.

The treatment of simple cut or incised wounds presents fewer elements of difficulty than do those forms of wounds which are accompanied by more extended damage to the adjacent tissues. In the arrest of hæmorrhage, which in general will be accomplished with but little difficulty, the means of hæmostasis should be adopted which will not be likely to introduce sources of disturbance in the after-course of the healing. Bleeding from all but vessels of considerable size will be arrested by exposure to the air, or by the application of hot water, aided by compression. The mutual compression of the wound-surfaces against each other, after they have been brought into apposition, serves to restrain any tendency to further hæmorrhage. When ligatures are required, only those that are aseptic should be employed, the preference being given to those of animal material that can be spontaneously absorbed.

The hæmorrhage from incised wounds in which large blood-vessels are opened seldom ceases spontaneously; they constitute the most dangerous class of wounds, and quickly terminate fatally from loss of blood. The most energetic and instant resort to measures for the arrest of hæmorrhage is called for in these cases. When a vessel is but partially divided, it is more difficult to stay the bleeding from it than if the division is complete. In such cases the first thing to be done after exposure and clamping or ligation of the vessel is to complete its division.

The cleansing of the wound is less difficult to accomplish; its surfaces are lined with a minimum amount of devitalized tissue, for the absorption and removal of which, without disturbance arising from its decomposition, the ordinary reparative energy of the adjacent tissues is usually quite adequate when coaptation is effected, even without minute precautions to exclude from contact with it, while exposed, any pathogenic bacteria. The drainage of incised wounds, when proper care is exercised to maintain their deeper parts in apposition, is very simple. In the more extensive wounds, it may be best to use capillary drains for the first twenty-four hours only, during the period of the most energetic afflux consequent upon the wound; in a large proportion of cases, where compression and immobilization of the wounded part can be effected, no provision for drainage is required.

The apposition of the wound-surfaces should be attended to with the utmost care and minuteness, so that by the use of sutures, compresses, bandages, and position, the coaptation of every part should be perfect, and no spaces be left for the collection of secretions. The reunion of parts which have been almost entirely separated from the body may sometimes be secured by minute attention to their coaptation. Albanese, of Palermo, Italy, reported at the session of the International Medical Congress at London, in 1881, a remarkable instance of such reunion. In this case the wrist had been almost completely cut through, with the bones and the flexor and extensor tendons, so that the hand hung, held to the forearm only by a slip of skin in the dorsal region about one and a half inch wide. The radial and ulnar arteries were ligated, the severed surfaces were brought into contact with pin sutures, and immobilization was effected by a plastic splint. Slight gangrene appeared in the thenar region. The temperature and sensibility of the hand and fingers were sensibly lowered for a long time. The vitality of the hand as a whole was preserved, and its reunion to the forearm accomplished with ankylosis at the carpal articulation, and mobility at the radio-carpal articulation. The fingers were at first immovable, but gradually acquired some movement, until finally they became quite useful.

The protective dressings required by incised wounds, the coaptation of whose surfaces is possible, are very simple. Exposure of the line of suture to the air, so that the desiccation of the slight amount of secretion

that gathers there may form a protective crust gives excellent results when the conditions of the wound are such as to make it practicable. A light, dry, clean absorbent dressing of some kind is all that is required at any time.

The provisions of "rest," in the case of incised wounds, may and should be made absolute. When proper care has been taken in other details of the treatment of an incised wound, that infraction of its rest involved in the removal and readjustment of its dressings may be long deferred; the surgeon can consider his dressing as having been perfect only when, after the expiration of a week or ten days, during which no local discomfort or constitutional disturbance having been noticeable, removal of the dressings and inspection of wound shows it to be healed throughout.

The development of inflammatory disturbance or of septic conditions, in the course of the repair of an incised wound, unless the inflammation and septicity were already present before it came under the care of the surgeon, is a reflection upon the character of the treatment, and calls for special explanation upon the part of the surgeon to exonerate himself from blame therefor.

CONTUSED AND LACERATED WOUNDS.

Since the extent of the tissue damage which has been sustained by the parts that are the subjects of contused or lacerated wounds is not to be determined by the amount of the apparent injury visible at the first examination, their treatment has to be conducted with a degree of care and watchfulness, and provision for probable causes of disturbance, that do not embarrass the surgeon in the management of incised wounds. The surface breach is generally much less than the breach sustained by the deeper tissues, and the wound is complicated by the presence of much tissue that has been damaged by the traumatism, the life of which is to be preserved only by great care in fostering its nutrition, and preventing the access of inflammatory disturbances.

The primary hæmorrhage from these wounds is less apt to imperatively demand the attention of the surgeon for its control than in the case of incised wounds, on account of the favorable condition of the parts for its spontaneous arrest produced by the nature of the traumatism, even

large vessels being frequently spontaneously plugged by the retraction and inturning of their separated inner tunic, and by the interlacing of the irregular ends of the external tunic and the surrounding connective tissue.

On the other hand, secondary hæmorrhages occur with more frequency on account of the sloughing of parts of the wall of a vessel, either because its vitality had been so far destroyed by the original force, which had yet fallen short of opening it, that it failed to become restored, and so ultimately necrosed, or because the vessel became involved in destructive inflammatory processes complicating the after-course of the wound.

The period during which the separation of sloughs caused by the original injury is taking place is thus a period of danger. This is usually between the sixth and twelfth days after the infliction of the wound. During this time, accordingly, special watchfulness against the occurrence of hæmorrhage is to be exercised.

The period of reaction from shock is also particularly liable to be complicated by hæmorrhage in the case of contused and lacerated wounds, since, though the blood-current, while weak from the depressed action of the heart, often finds the natural obstructions left behind by the laceration of the tissues sufficient to arrest it, yet when it is again driven with more energy by a restored heart, its force may be sufficient to sweep away these comparatively weak obstructions, and to determine copious hæmorrhage.

The period of reaction is therefore to be watched with especial care to guard against possible hæmorrhage; and in the first dressing of a wound involving vessels which may possibly bleed, it is the part of wisdom to apply preventive ligatures to them, though they may not be bleeding at the time, providing this does not involve undue disturbance of the wound in other respects. Aseptic ligatures should be used, and care should be taken to apply the ligature to a sound portion of the vessel.

Nevertheless, should a surgeon think it best to defer interference, as long as no bleeding takes place, it will be found that in many cases no interference will be necessary; but such a course will exact increased watchfulness until the repair of the wound has sufficiently far advanced to demonstrate the permanency of the spontaneous hæmostasis. When, however, secondary hæmorrhage has once occurred, then the application

of a ligature is imperative, even though the bleeding may have again spontaneously ceased as the heart's action has weakened, for so soon as the reaction again comes on, and the heart beats strongly once more, the hæmorrhage will surely recur.

The primary cleansing of the wound should be conducted with great care, the more since the recesses and irregularities, which its surfaces are likely to present, favor the lodgment of irritating matters, and because in many instances foreign matter is ground into the exposed surfaces at the moment of injury. All detached particles of bone and soft tissue should be carefully removed, and tissues into which foreign matter has been so ground that the complete removal of this dirt is impossible should be trimmed with scissors or knife. Bruised portions of tissue that are still attached should be carefully cleansed and replaced, and preserved from further traumatism, since much that appears to be hopelessly destroyed may yet be saved in many cases by care in fostering its nutrition.

Thorough irrigation of a contused and lacerated wound with an antiseptic lotion, until no element of sepsis be left within it, is imperative, for all the conditions of such wounds are such as to create and present to a large degree the material favorable for the rank development of septic organisms. The natural resisting power of the tissues, which enables the surfaces exposed in ordinary incised wounds to resist the development of sepsis, and to preserve the minute devitalized fragments of tissue that are present from undergoing septic changes, is no longer to be relied upon in the class of wounds under consideration; in these the bruised wound-surfaces have to struggle to retain their own vitality, and larger masses of devitalized tissue, and more copious effusions of putrefiable secretions have to be disposed of.

The consecutive cleansing of the wound, to admit of the free escape of wound débris of every kind during the period of repair, will require the fullest provision for drainage from all its recesses. All the methods of securing this, which have been discussed in the earlier part of this work (Chapter IX.), may find their application in the treatment of these wounds, and must be applied according to the judgment of the surgeon, so as to secure the immediate and full removal from the cavity of the wound of all putrefiable material as fast as formed.

Efforts at accomplishing apposition of the wound-surfaces must be

subordinated to the needs of drainage and the provision for the unhindered separation of necrotic tissue. In cases of severe contusion a degree of uncertainty will always exist as to the ability to regain vitality which the injured tissues may exhibit, and a certain amount of necrosis is to be expected and provided for. This necrosis will be reduced to a minimum in proportion as the provisions for making and keeping the wound aseptic are thorough and successful. When adequate antiseptic measures are practicable, greater efforts at securing coaptation of the wound-surfaces should be made, since they will be more likely to be rewarded with a certain degree of primary union than when antiseptic precautions are neglected. Special care should be observed to avoid all tension of the wounded tissues in endeavoring to approximate them. With this precaution, and those required for drainage, coaptation may be attempted by any of the means which are at the disposition of the surgeon for that purpose.

In a large proportion of contused and lacerated wounds there will be such an amount of destruction of tissue that any attempt at closing it to secure primary union will be manifestly contra-indicated. In such cases the efforts of the surgeon are chiefly directed toward protecting the wound from sources of disturbance during the time that the separation of the devitalized tissue and the repair of the breach by granulation is being effected.

These are the cases in which local septic inflammations, gangrene, erysipelas, and general septic infection are most prone to occur. For the prevention of these accidents the precautions of "antisepsis" and of "rest" should be rigorously observed.

Contused Punctured Wounds, such as those formed by the thrusting into the tissues of a splinter of wood, a nail, a bayonet, or any other substance which is capable of making a deep and narrow wound-track, are likely to present difficulties in treatment by reason of the trouble that they may give in securing their disinfection and drainage. The first thing to be attended to, after the removal of the puncturing substance and the stanching of hæmorrhage, if there be any, is the disinfection and cleansing of those parts of the wound that are accessible, and then placing the part at rest. If there has been no septic material introduced into the deeper parts of the wound at the time the puncture was made, and

adequate protection be afforded it thereafter, speedy repair without disturbance may be looked for. When, however, from any cause, inflammation of the deeper portions of the wound develops, in proportion as it is deep and narrow will the inflammatory effusions be pent up, and will follow the local and general phenomena of intense bacterial infection. They are septic wounds and require the immediate and energetic application of the means of treatment described as required by such wounds (Chapter IX., page 183).

The value of free and early incisions for the relief of pent-up effusions cannot be overestimated in such cases.

In the treatment of all infected punctured wounds the difficulty of providing efficient drainage is the chief problem to be solved. On the first appearance of local or general symptoms indicative of the presence of septic matter, an outlet by some means should at once be made, while the pent-up matter is still serous, without delaying until an extensive and unmistakable pus accumulation has formed. The early formation of a free vent for the secretions will be followed by relief, both local and general, and will almost always save tissue; whilst delay in adopting this practice is not only locally deleterious, but may even prove dangerous to life. When thecæ of tendons, fascial and fibrous coverings, as of bones, are involved, the necessity of adopting this practice is more important, if possible, than when only the softer tissues are implicated.

CHAPTER XV.

GUNSHOT WOUNDS.

Definition—Sizes of Various Missiles—Notable Tendency to Decrease Diameter of Missiles—The Modern Cylindro-conoidal Jacketed Bullet—Relative Penetration of Different Missiles—Deformation of Bullets—Usual Characteristics of Gunshot Wounds—Explosive Effects—Wounds by Shell-fragments—Injuries to Special Tissues—Special Conditions Attending Gunshot Wounds—Important Rôle of Septic Infection—Immediate Antiseptic Occlusion—Antiseptic Pads—Desiccation of Wound Secretions—Protest Against Routine Early Removal of Missile—Classification According to Treatment Required—Reyher's Statistics—Treatment Required for Open Wounds—Exploration and Cleansing—Probing—Removal of Bullets—Immobilization—Cases Requiring Joint Resection or Amputation—Removal of Imbedded Grains of Gunpowder.

THE term "gunshot wound" is applied generically to injuries inflicted by missiles, whatever their character, whose force is derived from the explosive power of gunpowder. This definition, therefore, includes every grade of missile, from the smallest birdshot to the immense projectile fired from mammoth pieces of heavy ordnance, and every grade of injury, from the mere peppering of the surface of the skin with grains of gunpowder or minute shot to the laceration and comminution of extensive portions of the body.

The mere explosion of powder fired from a gun at short range may produce a serious injury which combines the characters of a burn with those of contusion and laceration. The missiles which are more frequently met with in gunshot wounds are (*a*) the shot used in fowling-pieces, which are of various sizes, from that of a buckshot, which weighs 133 grains, to that of the smallest birdshot, one of which weighs only 1-5th of a grain; (*b*) pistol bullets, varying in size from about 1-5th of an inch to ½ of an inch in diameter, and weighing from 10 grains to 240 grains—the size of a pistol bullet is usually designated according to the decimal part of an inch which makes its diameter; thus a 22-calibre bullet is one whose diameter is 22 hundredths of an inch—(*c*) The rifle bullet, which

is the missile of the modern arm of precision, long and generally conoidal, and weighing from 3-8ths to 1½ ounces. For military use yet larger missiles have been devised which hardly arrive at the dignity of cannon shot, and yet are heavier than the rifle balls of the infantryman, such as the projectiles thrown by the mitrailleuse, Gatling, and Hotchkiss guns.

The tendency in the small arms used in warfare has been during the present century to steadily decrease in the diameter of the missile, and to increase in accuracy of aim, rapidity of firing, velocity of flight and penetration of impact. The smooth-bore musket in common use up to 1850 projected a round leaden bullet .75 of an inch in diameter. The Minié rifles of 1847 to 1855 had conical balls, .69 of an inch in diameter. In the Enfield rifles of the period from 1855 to 1871 the diameter was reduced to .577 of an inch, which was still further reduced in the Martini-Henry and the Springfield breech-loaders, of 1871 and after-years, to .45. In the weapons adopted at the present time in the armies of Europe and for the regular forces of the United States the calibre has been reduced to diameters varying from .315 to .2756 of an inch (Krag-Jorgensen, Mannlicher, Lee-Metford, Mauser, etc.). With these are used long, conical-ended composite bullets, of lead hardened by an admixture of tin or antimony, and enclosed in a mantle or jacket of cupro-nickel, or of steel coated with cupro-nickel.

By the use of powder of high explosive power, and by a more abrupt rifling of the gun-barrel, a muzzle velocity of two thousand feet, or more, per second is attained, with a rotation on its longitudinal axis of more than two thousand revolutions during the first second of its flight. At a distance of two miles they retain sufficient velocity to penetrate the human body. The penetrative power of these projectiles as compared with those in former use is shown in Figure 103, from the report of the Surgeon-General, United States Army, 1893.

The character of the injury produced when a gunshot missile has penetrated the tissues of the body is that of a contused, lacerated, punctured wound, but wide variations in the extent of damage done is presented in different wounds, dependent upon the shape and size of the missile and upon the velocity possessed at the moment of impact, and upon the tissues penetrated. With the more slowly moving bullet of the old large-bore weapons, the track made by the missile was much lacerated

and contused; its diameter was usually greater than that of the bullet; the bullets were often retained within the body, and it was not rare that for-

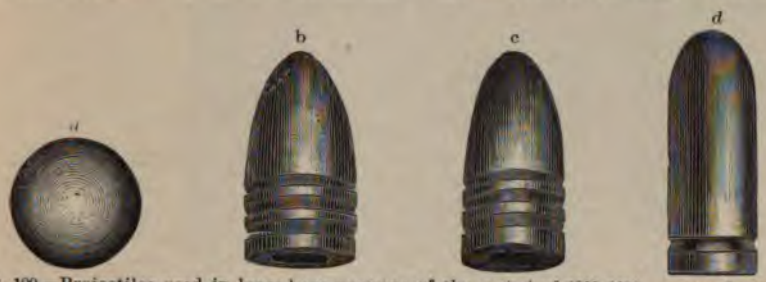

FIG. 100.—Projectiles used in large-bore weapons of the period of 1800-1890. *a*, round musket ball; *b*, Enfield rifle ball; *c*, Springfield rifle ball; *d*, Martini-Henry rifle ball.

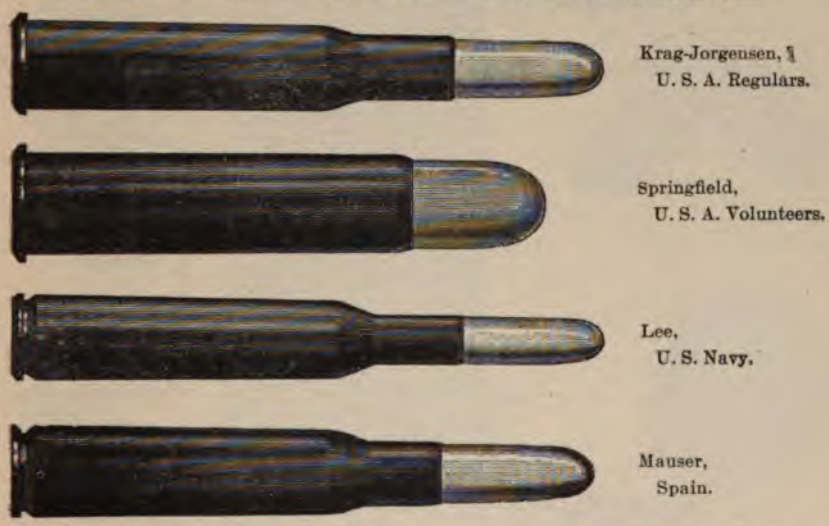

FIG. 101.—Modern small arm projectiles as mounted in metal cartridges ready for use.

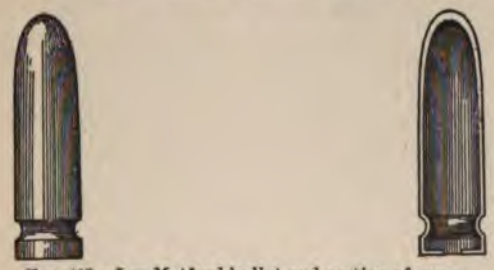

FIG. 102.—Lee-Metford bullet and section of same.

eign matter, such as portions of clothing, was carried into the wound with them. The soft metal of which the bullets were made frequently be-

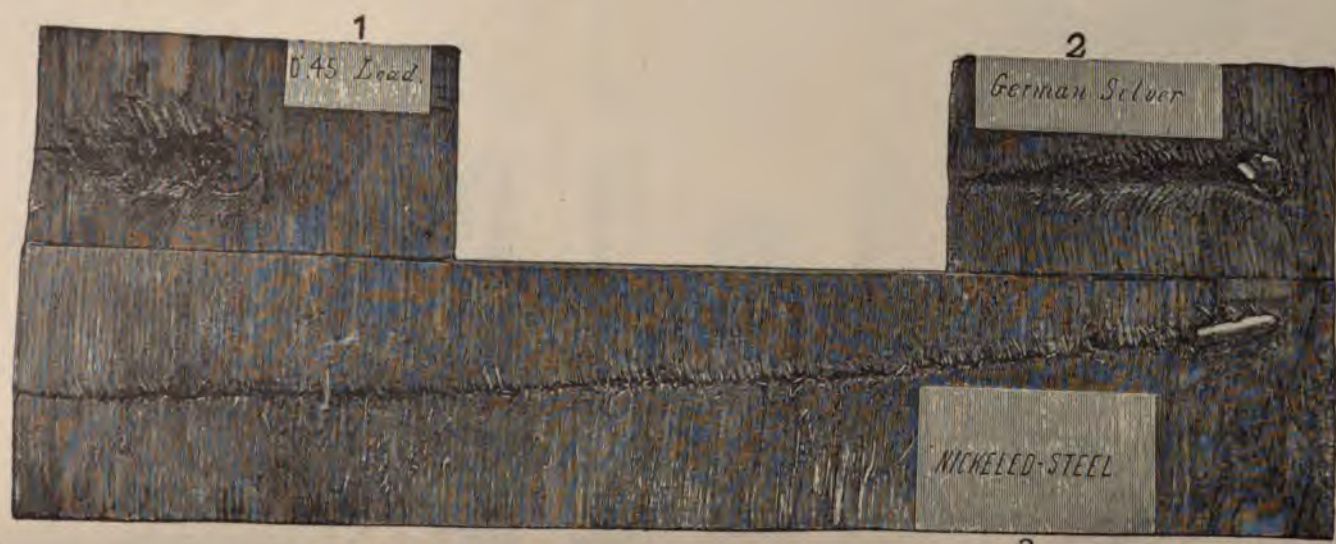

FIG. 103.—Relative penetration across the grain of oak of various projectiles (*La Garde*).

1. .45-calibre lead bullet; penetration. 3.2 inches. 2. .30-calibre German-silver jacketed bullet; penetration, 5.3 inches.
3. .30-calibre cupro-nickeled-steel jacketed bullet; penetration, 19.5 inches.

came distorted by contact with the harder tissues of the body, and by its expanded, ragged condition inflicted more widespread laceration.

The small calibre cylindro-conoidal bullet, according to the experience of the English in India and Africa, and that of the United States in Cuba, makes a wound that, as a rule, is a clean punctured wound, rarely being arrested in the body, but perforating it with a wound of exit but little if any larger than that of entrance, attended with but little bleeding, unless a large vessel is cut. The bullet rarely deforms, even on impact against resisting bone, and rarely carries clothing or infectious material into the wound.

FIG. 104.—Distorted bullets. Specimens in the U. S. Army Medical Museum.

Explosive Effects.—On the other hand, in some instances, most extensive and destructive wounds have been caused by them, bones being extensively shattered, and soft tissues lacerated and pulpified, and such organs as the brain and heart disorganized as if by an internal explosive force. These effects have been more frequently produced at short ranges, 300 yards and less. Wounds inflicted at very long ranges, 1,800 yards and more, are also reported to be frequently characterized by great shattering of bone and contusion of soft tissue, while in the intermediate zone clean penetration is the rule. Since, however, the great majority of wounds are received at a comparatively close range, and the explosive

effect is only an occasional and rare result, it is evident that it is not determined by the range alone, but is the effect of the peculiar condition of the tissue when struck by the missile with its high velocity. It is quite evident that the power of a bullet cannot vary by bounds, but that its effect, as the range increases, must steadily and gradually diminish, and that accordingly a gradual and perceptible diminution of the effect of the bullet must take place as the range increases. Different parts of the body offer different resistances according to their construction and physical condition, and therefore one part may, at a given distance, receive very serious and complicated damage, while another may be simply perforated. The damage sustained by soft organs penetrated by a bullet with high velocity is perhaps best explained by the assumption that to the elements of the organ are communicated vibrations of intense energy by the missile, a tremendous centrifugal velocity being imparted to all the constituent particles as the missile pushes its way along, to be followed by a corresponding rebound to fill the vacuum behind the advancing ball. The surrounding tunic of the organ, whether of fibrous or bony tissue, may be ruptured by the primary centrifugal force, permitting the flying apart of the lacerated tissue, or it may resist it sufficiently to confine the effects of the vibration within the investing tunic, and producing greater pulpification of the elements of the organ.

The compact tissue of the shafts of long bones, and in the body of such bones as the inferior maxilla, the scapula, and the ilium, presents physical conditions especially favorable for the development of such vibratory effects, and, experimentally, such effects have been demonstrated in them. In the German experiments (von Coler) the greatest destruction was at 37 yards and the least at 2,200 yards. Hits at ranges up to 220 yards were distinguished by extensive destruction of the bones and of the soft parts behind them. The nearer the bullet struck the bone at its greatest diameter the greater the destruction produced both in the bone and in the soft parts beyond; but even with grazing shots severe splintering of the bone and extensive pulping of the soft parts were observed. The intensity of the splintering diminished with the increase of the range, but the longitudinal extent of the fracture lines was equally great at all ranges. Perforations of spongy osseous tissue, as in the epiphyses of long bones and the bodies of the vertebræ, etc., presented many

fissures radiating from the bullet track, and abundant bone particles and small splinters on the exit side, but the periosteum frequently remained untorn and kept the fragments bound together.

Wounds by Shell-fragments.—The irregular jagged pieces of metal which result from the explosion of a shell possess much less velocity and penetrative power than the rifle ball, and hence inflict more superficial wounds, attended with much contusion and laceration, and very frequently with the lodgment of the fragment in the body. Its mass and velocity may, however, be such as to carry away a limb, or produce an extensive excavation of a part of the body. In other cases a large fragment may bury itself in the soft tissues, through an apparently small wound of entrance. The contusing effects of such an injury are widespread, much greater than the appearances presented at first by the injury would indicate, in this respect resembling the injuries resulting from the impact of the wheels of moving railway cars. In addition to the extent of the devitalization attending such injuries, their infection by septic material carried into them upon or with the missile, or from contact with septic material from many probable sources, is difficult to prevent, while the wound conditions are such as to favor the development of intensity in any septic processes once inaugurated.

Gunshot wounds derive especial significance from—1. The special tissue or organ injured; 2. The conditions under which the wound was inflicted; 3. The presence or absence of septic infection.

Injuries to Special Tissues.—*The Skin.*—The effects of grazing the skin and of contusion without penetration have already been referred to. When a penetrating wound has been inflicted, the wound of entrance is generally small and less in diameter than that of the missile itself, owing to the elasticity of the skin, which has been stretched by the ball before being penetrated by it. It is also apt to be dirty, both from the powder, if the wound was at short range, and from wiping the dirt from the ball as it enters. Such a wound will appear insignificant to one unfamiliar with its real gravity. Should other foreign matter be carried in with the ball, the wound of entrance will be correspondingly increased in size. Should the ball pass clear through the body or limb, the wound of exit will be larger and more ragged than that of entrance, the difference being determined by the lessened momentum of the ball and the want of

support to the tissues at the point of exit, as a nail driven through a board splinters largely the under side or point of exit. Conical bullets, having greater penetrating power than round, produce in the skin-wounds which they make much less difference in size than formerly resulted from the use of round bullets. By subsequent sloughing of the contused margins of the wound of entrance it often becomes after a few days of greater magnitude than that of exit.

Fasciæ.—Especial interest attending wounds of fasciæ arises from the fact that their interlacing fibres are often to a considerable degree split and crowded aside by the ball as it passes through them, so that the orifice that they present is much less free than is found in the softer tissues on either side, and tends to interfere materially with the drainage of the deeper parts of the wound. Dense fasciæ again frequently present sufficient resistance to a ball if it is a round one to deflect it from its original course.

Muscles, when involved, are subjected to widespread damage through contusion and laceration of their substance and extensive infiltrations of blood.

Tendons, by reason of the resisting nature of their structure and their roundness and mobility, are most frequently either pushed out of the way or deflect the bullet.

Blood-vessels, especially arteries, whose walls are more resistant and elastic than those of veins, are not infrequently pushed aside in case of wounds inflicted by slow-moving bullets of large calibre. Even in such cases, however, such contusion of their structure is often inflicted as to determine subsequent sloughing and secondary hæmorrhage. Both partial and complete division of large blood-vessels is a frequent concomitant of gunshot wounds, and is also the most frequent cause of immediate death by reason of the hæmorrhage following. Traumatic aneurysm and arterio-venous aneurysm may result in certain cases, as has already been noted in ordinary punctured wounds.

Nerves.—Large nerve-trunks when wounded present no special symptoms that call for extended notice here. The functional disability resulting from such wounds will depend upon the special function of the particular nerve, and may be more or less complex and important. Severe pain may result primarily from inflammatory processes in the injured

nerve, or later from being involved in a contracting cicatrix or by development upon its end of a neuroma. Trophic changes of every degree are among the ultimate results of nerve-injuries.

Bones.—A ball striking upon a bone, if it retains any momentum, will inflict much damage upon it, splitting and comminuting it, often producing fissures that extend into neighboring joints. The bullet may become lodged in the bone, remaining as a source of irritation, and often of suppurative inflammation, until removed. (See Chapter XVIII., Wounds of Bones.)

The Great Cavities of the Body.—Balls penetrating the cranial cavity will produce symptoms according to the region of the brain injured; though always serious, the wounds they inflict are not necessarily fatal. Penetrating wounds of the thorax may involve the lungs, the heart, or the great vessels, and, if not immediately fatal, present special difficulties in counteracting inflammatory complications or in overcoming the results of extensive pleural or pericardial effusions. Penetrating wounds of the abdominal cavity, in addition to the dangers from hæmorrhage and from ordinary inflammatory complications, have the special dangers incident to possible wounds of the stomach, intestines, bladder, and the various other abdominal viscera. (See Wounds of the Abdomen and Its Viscera.)

The Conditions Under Which the Wound is Inflicted.—Gunshot wounds differ especially from the ordinary operative wounds inflicted by a surgeon in the special conditions incident to warfare which make it difficult, often impossible, to give to the patients the full degree of care which they require, and which often expose them to further injury and damage that greatly aggravates the original severity of the wounds. In dealing with these conditions is found the special field of military surgery. In civil life, however, it often happens that gunshot wounds are sustained under conditions that resemble those of military campaigning, as in the case of accidental wounds occurring among hunting-parties in regions remote from help. The frequent absence of skilled help and of the necessary materials for the proper dressings for such wounds adds greatly to the dangers which attend them. The necessary transportation of wounded men for long distances, often with the most crude resources for their comfort, is another fruitful source of evil, and has many times demanded the sacrifice of a limb or has occasioned

the loss of a life which under more favorable circumstances could have been saved. In the accidental gunshot wounds of civil life also it is by no means the rule that adequate surgical skill and proper dressing materials are at once attainable.

THE PRESENCE OR ABSENCE OF SEPTIC INFECTION.—This is a factor of the highest importance in determining the favorable or unfavorable course of a gunshot wound. If such a wound is preserved from septic infection, the wound of entrance is quickly closed and its remaining track, however long it may be, or however much lined by contused necrotic tissue, or whatever organ it may have traversed or bones it may have shivered, is reduced to the condition of a subcutaneous injury, and is thereby saved from a thousand dangers that might otherwise complicate its healing. Fortunately, experience has shown that in many instances a penetrating bullet does not carry with it septic material, and that if a wound which has been thus made is preserved from subsequent infection, an aseptic course of healing will take place. The question of the removal of the bullet itself in such cases becomes a secondary matter, depending entirely upon the importance of the later symptoms of disturbance which its presence in the tissues may occasion. On the other hand, the introduction of sepsis into a gunshot wound is sure to determine inflammatory and suppurative symptoms of the most pronounced type, and to call for the most energetic and thorough interference on the part of the surgeon. Secondary hæmorrhages are to be feared; necrotic débris and the pent-up products of septic inflammation will require to be evacuated; increased dangers to life and limb will be incurred; and in the most favorable event a prolonged convalescence will result.

TREATMENT.—The principles of treatment which are applicable to contused and punctured wounds in general find their most important application in the treatment of gunshot wounds, and by their scrupulous observance the repair of these wounds will be greatly facilitated and the occurrence of the wound-disturbances, which are prone to manifest themselves as the sequelæ of gunshot wounds, will be avoided.

HÆMORRHAGE.—Special interference for the arrest of hæmorrhage is only likely to be demanded in the case of wounds of vessels of considerable size; in such cases the rule is imperative to enlarge the wound, expose the bleeding vessel and ligate it upon both the proximal and distal side of

its wound. Should the vessel not have been already completely severed by the ball, it should be divided between the ligatures after their application.

When the wound-track is in the vicinity of a large vessel, the possibility of secondary hæmorrhage should be borne in mind, and special watch be kept upon the case till its repair has sufficiently advanced to make such danger no longer to be apprehended.

WOUND-CLEANLINESS.—The cleansing of the wound involves the measures necessary for its exploration, the removal of the missile and other foreign matter that may have been carried in with it, and the destruction of sepsis.

The relative importance of these measures appears from the fact that the disastrous results of gunshot wounds, which are not quickly fatal from the vital importance of the parts damaged, are always consequent upon the infective disturbances which complicate their repair. These disturbances have their origin in septic contamination of the wound-track, and gain their aggravated proportions from the natural obstacles which the wound-track presents to the escape of the septic matters afforded by the contaminated wound-secretions and débris.

The prevention of the septic contamination of the wound-track, therefore, is to be considered as of the greatest importance to be observed in all the manipulations to which it may be subjected, and is to be kept in view from the first moment that the wound is received. The presence of the missile, or other foreign substances carried in with it, or splinters of bone, are less to be feared than the subsequent introduction of septic elements.

Immediate antiseptic occlusion, that is, the application to the external wound, or wounds, of tampons of absorbent antiseptic material, as early as possible after the infliction of the wound, should be done; for no period of time, no matter how small, can be safely allowed to elapse between the reception of the injury and its protection from septic invasion.

In military practice the immediate cares before the wounded man has been transferred to the field hospital, some miles at least in the rear, or in civil life, in the accidental wounds received in hunting expeditions, or in those cities in which the immediate aid of an ambulance surgeon is rendered, should be confined to the arrest of hæmorrhage, occlusion with an antiseptic tampon, and the application of means of immobilization.

Above all should the search for bullets, or bone splinters, or foreign material, be postponed until full and efficient means to prevent the infection of the wound are available. Absorbent cotton impregnated with iodoform, salicylic acid, or boracic acid may be selected for such immediate occlusive purposes. The antiseptic balls recommended by Esmarch to be supplied as a part of the outfit of a soldier were made of salicylic wool and jute, contained in salicylic gauze, and enclosed in a square of oiled paper. The tampon to be invariably applied directly to the wound, and the oiled paper used as an external covering. The whole secured with a bandage.

The package recommended by Senn consists of half an ounce of compressed salicylated cotton, in the centre of which is further placed 40 grains of boro-salicylic powder (boric acid, 4 parts; salicylic acid, 1 part; thoroughly triturated together); this mass of medicated cotton is wrapped in a triangular gauze bandage, and the whole, with a safety-pin added, is sealed up in an external envelope of guttapercha tissue. This package should be fastened to the inner surface of the cartridge-belt, rather than stitched to any part of the clothing.

When no antiseptic protective substance is immediately attainable as a covering to the wound, it should be left exposed to the air without any covering whatever, inasmuch as the air is less likely to be a source of sepsis than any ordinary dressing which would otherwise be applied. By such exposure, also, desiccation of the secretions about the wound aperture would be favored, and a protective crust thus be formed.

When the necessity of interference with the wound for the arrest of hæmorrhage is present, its urgency may compel the disregard of every other precaution; but, with that exception, it should be considered an absolute rule that nothing should be brought into contact with it for any purpose which has not been previously rendered aseptic, and that all interference of any kind is to be abstained from until it is possible to surround it with the necessary provisions against sepsis.

When no septic matter has been carried in with the bullet, and no septic matter has been introduced by the surgeon in explorations or efforts at removal of the missile, and early sealing of the external wound has been accomplished, either by the scab formed by the desiccation of its discharges, or by occlusion with an antiseptic tampon, the wound is re-

duced to a subcutaneous injury, and the greater part of the difficulties in its treatment become eliminated.

The chief obstacle to the general adoption of the practice of primarily sealing up the external aperture of a gunshot wound lies in the undue importance which has been attached to the early removal of the missile, when embedded, as if the foreign body in itself was the exciting cause of the disturbances of repair that mark the usual course of the healing of such wounds.

On the contrary, as Esmarch expresses it, "the damage done by the bullet is caused by it in its course; the harm that is added comes mostly from the examiner's finger."

Reyher,[1] in detailing the remarkable results obtained, under his direction, in the Russo-Turkish war, remarks: "I have never explored for the purpose of extracting bullets; never even, for this sole purpose, after patients had reached the hospital. In the hospital I have only removed them when their removal seemed imperative on account of inflammation or suppuration in their immediate vicinity. In a large number of cases, then, the parts have healed around the bullet, in spite of the generally accepted ideas of practice to the contrary. It is not impossible that in some of these cases the foreign body may prove a source of future irritation, but its extraction subsequently in private practice will be much less dangerous than in the infected atmosphere of a military hospital, while its removal, then, will be from tissues which are no longer infiltrated, and from which all blood-extravasation has long been absorbed."

The mere lodgment of a bullet, therefore, in the tissues, is not of itself a sufficient indication for opening up the wound-track by an exploring finger or probe, and exposing the wound to the dangers of septic contamination which such a manœuvre would entail, nor, even if the exploration was done with adequate antiseptic precautions, would it be justifiable to disturb the wound by the new traumatism of the exploration, until distinct evidence had appeared that the missile was seriously disturbing the repair of the wound by its presence.

IMMEDIATE EXPLORATION of a gunshot wound is called for only in cases in which the manifest nature of the wound is such, by reason of

[1] *Die Antiseptiche Wundbehandlung in der Kriegschirurgie.* Volkmann's *Samml. klin. Vorträge*, No. 142, August, 1878.

the extensive laceration and destruction of tissue present, that its occlusion is impracticable, and the questions of excision and amputation require to be decided.

CLASSIFICATION OF GUNSHOT WOUNDS.—Gunshot wounds thus divide themselves, from the standpoint of treatment, into two classes: 1, Those which are capable of primary occlusion of the external wound, and of conversion into practically subcutaneous wounds; and, 2, those which must be treated as open wounds throughout.

By immediate provision for the protection of the wound from septic contamination from without, and by careful abstinence from any explorations of it, until the symptoms of inflammatory disturbance declare that interference is necessary, an aseptic course of the healing of the wound may be secured in a large proportion of cases. Reyher, in his observations before alluded to, has recorded the following valuable statistics of the comparative safety and value of such attempts to occlude gunshot wounds.

Out of twenty-eight cases of gunshot wound of the knee with bullet embedded in the part, the four which were treated in accordance with these principles, *from the outset,* recovered with movable joints; eight, in which antiseptic precautions were not adopted until the next day, died, as well as four which had no such treatment at all; while of the remaining twelve, which had no *primary* antiseptic treatment, and required either intermediate or secondary amputation, eleven died. Of forty-six cases of wounds of different joints treated as above, six died—mortality 13 per cent.; of these, nineteen required primary resection, of which only two died—10.5 per cent. Of seventy-eight cases similar in other respects, but in which antisepsis was a secondary consideration, or from which bullets had been extracted, forty-eight died—61.5 per cent. Of another series of sixty-two shot wounds of joints without primary precautions, thirty-nine died—63 per cent. So in cases of shot fractures of long bones, of sixty-five treated from the first, only five died—7.6 per cent. Of twenty-nine not so treated, eight died—27 per cent. In a neighboring hospital to his own, during the campaign in the Caucasus, Reyher saw seven cases of uncomplicated wounds of soft parts die of pyæmia; under his own primary antiseptic measures he lost but one such. In another series of sixty-five fractures treated secondarily by antiseptic

rules, twenty-three died—35.3 per cent. As illustrating the reduced number of cases of pyæmia, altogether of eighty-one cases of miscellaneous wounds treated primarily, only five died from blood-poisoning—6.1 per cent.; whereas, of one hundred and forty-three not so treated, forty-six died—32.1 per cent. Of fifty-seven various wounds of skull, buttocks, and soft parts, all treated antiseptically from the start, *not one died.*

With all his cases, Reyher saw erysipelas but three times. There were, moreover, but two cases of tetanus, and none of gangrene. The number of lives saved by the adoption of this method by Reyher was, therefore, in proportion, from three to four times as many as were saved under the older methods. Out of the forty-six cases of gunshot wounds of joints it was only necessary in *four* cases to depart from the system of primary occlusion without interference; whereas, of seventy-five cases of similar wounds treated by secondary antisepsis, drainage, etc., in fifty-four of them resections or amputations were required.

The second class of cases, which must be treated as open wounds, includes those in which the extent of the external wound is too great to give any hope of securing its primary occlusion, those in which these attempts have been made but have failed, and those in which such attempts have been deferred or omitted until the wound has become manifestly septic, by reason of its exposure, its having been subjected to uncleanly and premature explorations, or the application to it of contaminated dressings.

Even in this second class of cases, all explorations and other operative measures should be deferred until they can be done with the necessary precautions against septic contamination, or can be accompanied by adequate protective antiseptic dressing.

Treatment of Open Gunshot Wounds.—The treatment of this class of gunshot wounds should be conducted with scrupulous attention to the thorough disinfection of every accessible recess of the wound and to perfect freedom of drainage. The appearance of high fever, inflammatory swelling, progressive infiltration, gangrene, and other evidences of progressive septic contamination, calls for the energetic and thorough application of all the resources for the destruction or control of sepsis which are within the command of the surgeon.

The primary examination and cleansing of the wound should be conducted with the view of making it aseptic. Frequent partial cleansing should be avoided; repeated probings, cuttings, irrigations, and squeezings for the purpose of evacuating wound-secretions and débris, which keep up a continual irritation of the wound, should be replaced by a thorough primary examination and cleansing. This must be conducted with deliberation and minute attention to the ultimate object in view—the destruction and prevention of sepsis. An anæsthetic should be administered, and everything brought in contact with the wound should be carefully disinfected as used (see Chapters IV. and VI.).

The external wound should be freely enlarged, when necessary, so as to permit the introduction of the cleansed and disinfected finger for purposes of exploration. For the purposes of enlarging the deeper part of the track, if the vicinity of important organs or the dangers of hæmorrhage make the use of the knife undesirable, it may be enlarged with blunt instruments, as dressing forceps introduced closed and then opened and withdrawn, thus acting as a dilator. The ordinary glove-stretcher suggests itself as a model for such a dilating forceps.

Bullets, splinters of bone entirely detached, pieces of clothing, and other foreign bodies, which are found during the examination, should be carefully extracted.

A bullet not infrequently, after having in the early part of its course inflicted injuries which require to be treated by the open method, continues its course in such a manner that the second part of its track may heal primarily behind it, and the bullet remain shut off from the first part of the wound, and then, becoming encysted, permanently remain without inducing further mischief.

The treatment of such a deep wound-track should be conducted on the same principles as those which control the treatment of the more superficial wound. It should not be probed, nor irrigated, nor in any manner interfered with, until evidences of inflammatory disturbance of its walls appear. No search should be made along it for the bullet, much less should the mere presence of the bullet at its bottom be considered an indication for an attempt at its removal. The disinfection and drainage of the superficial portion of the wound should be conducted with all care and thoroughness. Should disturbances of the deeper portions of the

wound manifest themselves, the exploration, cleansing, and drainage of that portion of the wound would then be required. Enlargement of the aperture of communication with the superficial wound, and free counter-incisions to the extent required for its easy and perfect drainage, and for the removal of any foreign and irritating bodies along its track will be necessary.

Probing a Wound.—When the circumstances of the case or the symptoms which are present make it important that the deeper recesses of the wound should be searched, this is to be accomplished by the insertion of the finger of the surgeon if possible, or by the use of suitable probes, and all the steps of the process of the search should be conducted with most careful regard to the requirements of rigid asepsis. Such probings are not to be done as a matter of routine, but only when some distinct indication is present. Free enlargement of the external wound should be made without hesitation whenever it will facilitate the prosecution of the search, and as far as possible reliance should be placed upon the finger of the surgeon for gaining the desired information to the exclusion of metallic or other probes.

For probing, a blunt-pointed, flexible rod should be used; the probing extremity should be sufficiently large, so that it should not easily make a passage for itself among the tissues; the shaft should be flexible, so that it may be adapted to the particular course of the track that is being explored, and should be long enough to admit of being easily and definitely controlled by the hand of the surgeon. Such a probe having the tip made of porcelain biscuit, and known as Nélaton's probe, has the special value that when the tip comes in contact with the bullet at the bottom of the wound it retains the mark of the lead upon it, and thus gives an absolute demonstration that it has been in contact with the bullet. Before using it its freedom from any similar prior stains must be ascertained. The stem of an ordinary clay pipe has been used extemporaneously for the same purpose. The "telephonic probe" of Girdner is an ingenious and reliable application of the telephone for identifying the location of a bullet in the tissues. This device may be extemporized whenever an ordinary telephone receiver is accessible; one of the wires of the telephone having been attached to the probe, the other is made fast to any metallic plate, which is now placed upon any portion of the sur-

face of the body previously moistened. The probe is now inserted into the wound for the purpose of the search, while the telephone receiver is held to the ear of an assistant; whenever the probe comes in contact with the bullet a distinct click is heard in the telephone—a click which is not elicited except by contact with metal. Other methods for utilizing the electric current for detecting and locating a bullet imbedded in the tissues have been devised; some of these are ingenious and successful as experiments, but none are susceptible of being utilized in general practice.

Rods of copper, silver, or pewter, a foot in length, with bulbous extremities of the diameter of an ordinary goose-quill, offer themselves as suitable material for probes. In an emergency the ingenuity of the surgeon will not fail to find some material from which a probe may be extemporized, although adherence to the rules which should guide the treatment of wounds, as given above, will remove explorations altogether from the list of operations of emergency.

Probing a wound should be done with all possible gentleness and care. The probe should be carefully cleansed and disinfected at the time of being used. It cannot be too strongly impressed on the mind of the surgeon, however, that all probing of a wound should be abstained from until such time as the final thorough examination and dressing of the wound can be performed, when once for all, the use of the probe may be required in accordance with the restricted indications for its use which have been mentioned.

The Removal of Bullets.—When relegated to its proper place as a minor part of the general provisions for obtaining wound-cleanliness, the search for and the removal of the bullet calls for less consideration as to the methods by which it may be accomplished, and the apparatus needed for its technique, than when it was esteemed in itself an indication of first importance to be met. Forceps with slender and firm jaws, with slightly projecting teeth that may increase the security of the grasp of the forceps upon the bullet, will facilitate the removal of a bullet when exposed. A blind groping for a bullet at the bottom of a deep sinus should not be attempted; the enlargement of the external aperture, and the dilation of the deeper track, as required for the purposes of cleansing and drainage of a wound, or the counter-incisions made when the length

and location of the track demand it, should be ample enough to permit the sufficient exposure and ready seizure of the bullet, if it is to be removed at all.

When the ball is suspected of having become impacted in a bone, or to have penetrated a joint, it is not to be interfered with, nor is an exploration for the purpose of determining the fact to be made, unless the wound, for other reasons, demands treatment as an open wound, or the efforts to secure primary occlusion have failed. If, upon exposure, it is loosely held, it may be readily removed; if firmly impacted, it may be loosened by means of an elevator or chisel, and then removed.

Immobilization of parts which are the subjects of gunshot wounds is of extreme importance. Means of immobilization should be adopted as a part of the first dressing, it should be made continuous and absolute, and will prove a powerful accessory to the local antiseptic dressings in securing permanent primary occlusion of a wound.

Cases Requiring Joint Resection or Amputation.—Aside from penetrating wounds of the cavities of the body, and injuries of the large vessels, the great majority of those gunshot wounds which are likely to be complicated by dangerous wound-disturbances are those which involve bones and joints. A certain proportion of these injuries will require primary resections of joints, partial or complete, and amputations, as a part of the care required in the primary dressing. The necessity for these more important operative procedures will have become revealed in the course of the explorations which have been made. The judgment and experience of the surgeon as to his ability to ward off the dangers which threaten badly shattered joints and bones and extensively-mangled soft tissues, and to conduct the wound to a satisfactory healing so as to preserve a useful limb, must influence the decision in many cases as to whether a conservative method of treatment or the opposite should be adopted. In yet other cases, when, in addition to extensive injury to a bone or penetration of a joint, the main vessels or nerves of the limb are injured, or when extensive loss of the soft tissues has taken place, or when a part of the limb has been carried away, no alternative is left to the surgeon but amputation.

When the necessity of amputation is unquestionable, it should be done as soon after the shock from the primary wound has passed away as is

practicable, provided this is before septic infection, inflammatory infiltration, and secondary traumatic fever have developed. This is the period characterized by old authors as the *primary period;* which, in pre-antiseptic days, consisted generally of from thirty-six to forty-eight hours. This was followed by a period extending over a variable time, during which there was progressive local inflammatory infiltration and general fever. This period was termed the *intermediary period.* During this period no operative interference is to be attempted other than that required for the removal of necrotic tissues or for affording adequate drainage, unless spreading gangrene of the wound develop, when distant amputation through tissues yet sound should be done as quickly as possible. When the primary inflammatory infiltration has become limited and begins to subside, and free suppuration from the wound-surfaces has become established, another period is said to have been reached, known as the *secondary period.* When the secondary period has been reached, amputation through tissues yet sound should be done without further delay.

The prolongations of the primary stage by antiseptic treatment—continuous antiseptic irrigation being the method which in general is best adapted to these cases—makes it possible for the surgeon to delay amputation until such time as, in his judgment, the patient will be in the most favorable condition to bear the operation. In some cases it will happily have served to demonstrate the possibility of recovery without amputation, for in not a few instances the possibility of saving a limb will depend entirely upon the success of the efforts to prevent the wound from being invaded by septic infection. As soon as it is evident that these efforts have not been successful, amputation should be proceeded with, before the full local and constitutional symptoms of sepsis have developed.

Point of Amputation.—The choice of the point at which the amputation shall be made may be greatly influenced by the facilities at the command of the surgeon for keeping the wound aseptic. If these be adequate for the purpose, the section may be made at whatever point may be desirable to give the patient the most useful stump, even though bruised and lacerated parts be included in the flaps. These are preserved from inflammatory disturbance, their full vitality is regained, and they participate in the formation of the stump without disaster from

sloughing. When, for any reason, the wound cannot receive adequate antiseptic treatment, amputation, if possible, should be made at a point sufficiently far above the injury to exclude all bruised and lacerated tissues from the flaps.

Gunpowder grains imbedded in the skin may be picked out by a sharp-pointed bistoury and a fine curette, or be left to spontaneous discharge by suppuration. In any event, a permanent tattooing will remain as a mark of the wound.

PART II.

SPECIAL WOUNDS.

SECTION II.

WOUNDS OF TISSUES COMMON TO ALL PARTS OF THE BODY.

CHAPTER XVI.

WOUNDS OF MUSCLES—TENDONS—NERVES.

Wounds of Muscles—Difficulties of Coaptation—Position—Bandaging—Suturing—Rest—Protection from Sepsis—Subcutaneous Ruptures—*Wounds of Tendons*—Healing of Subcutaneous Wounds—Difficulties of Open Wounds—Importance of Antisepsis, Protection, and Rest—Suturing Tendons—*Wounds of Nerves*—Degeneration of Distal Segment—Axis Cylinder Buds from End of Central Segment—Regeneration of Distal Segment—Importance of Approximation of Divided Ends—Methods of Approximation—Suturing Nerves—*Application of the Nerve-suture*—Direct Nerve-suture—Peri-neural Suture—Secondary Suture—The Suture Material—Conditions Requiring Nerve-suture—Neural Infixation—Neuroplasty—Tubular Suture—Contra-indications—Requisites to Success—After-treatment.

WOUNDS OF MUSCLES.

THE retractile nature of the muscular tissue, by its tendency to cause wide separation of the divided ends of an injured muscle, occasions special difficulties in the treatment of wounds of these organs. In order to bring the wound-surfaces into apposition it is necessary that the part be placed in a position of complete relaxation, in which it must be kept during the course of the healing, till firm union has taken place. When it is a muscle of one of the extremities that is wounded, the continued relaxation of either portion will be promoted by the application of two roller-bandages, applied in opposite directions, each beginning at that part of the muscle most distant from the wound, and approaching the wound as they are applied. Thus the contraction of the fleshy fibres may be controlled, and the approximation of the retracted ends favored.

The permanent functional impairment which is entailed by a failure to secure approximation and union of the divided ends of a muscle, lends importance to every means which can be adopted which will prevent such failure. Sutures should be applied—sutures of relaxation and of coapta-

tion—the deeper sutures being carried through nearly the whole thickness of the muscle. Rest by means of position, compression, and immobilization should be maintained with great care. When adequate protection against the causes of inflammation is neglected, approximation by sutures will be of little value, since the softening of the tissue, even to some little distance from the surface of the wound, consequent upon the inflammatory changes, will cause them to be easily torn out. Every precaution, therefore, of wound-cleanliness and of antiseptic dressing should be observed in the care of this class of wounds, to prevent the production of septic disturbances.

In the treatment of subcutaneous ruptures of muscles, when the muscle is one whose function is of importance, and is so situated that it is accessible without endangering more important organs in the operation, the protection of the unbroken skin should be sacrificed, and the wound converted into an open one, in order that the more important indication of bringing the retracted ends into coaptation by sutures may be accomplished. Should the edges of the wound across the muscle prove to be ragged, they should be trimmed sufficiently to permit of close apposition of the surfaces.

Subcutaneous muscular ruptures which are too deep-seated, or which are complicated with other injuries that make their exposure by incision inadvisable, should be treated in accordance with the general methods described for the management of subcutaneous injuries.

WOUNDS OF TENDONS.

Approximation of the divided ends of a severed tendon must be favored by placing the part in that position which will fully relax the attached muscle; appropriate means of immobilization and compression must then be used to prevent retraction and separation during the period of repair. The healing of subcutaneous wounds may be expected to progress undisturbed without other treatment, if these precautions be observed. Divided tendons, in which the injury has been accompanied by a simple punctured wound of the skin, as in the operations of tenotomy for orthopædic purposes, in which immediate occlusion of the external

wound is accompanied by its healing by primary union, require the same simple treatment as if the wound had been absolutely subcutaneous from the first.

Open wounds exposing divided tendons present conditions especially favorable for the development of wound-disturbances, which conditions are still more aggravated in those cases in which a synovial sheath for the tendon is likewise opened. The retraction of the tendon-fragments prevents approximation and primary union, and leaves recesses for the accumulation and retention of secretions; the synovial sheaths offer favorable material and surfaces for the development of sepsis, and in their absence the connective-tissue that ensheaths the tendon affords a favorable tissue for the development and extension of phlegmonous inflammations. A strict observance of every detail of wound-cleanliness and disinfection is therefore necessary in the treatment of open wounds of tendons. Perfect arrest of hæmorrhage must be accomplished. The primary cleansing of the wound must be scrupulous, and adequate means for drainage must be provided. The ends of the divided tendons must be sought for, and their coaptation effected and maintained by sutures. It is less essential what the exact kind of suture it is that is employed, than that it be aseptic and of sufficient durability to maintain the coaptation till the union shall be firm. The suture should be passed through the tendon sufficiently far from its edge that it shall not be easily torn out. The external wound should then be closed, with due attention to drainage. Protective dressings and provisions for rest should be applied with minute care.

The treatment of wounds involving tendons, in which suppuration or inflammatory disturbances have already declared themselves, must be conducted in accordance with the methods governing the treatment of such wounds in general. The suture of the tendon-fragments will have to be abandoned or omitted in such cases, and their direct union left to be accomplished by operative measures at a later period, after cicatrization of the wound has been effected.

When marked impairment of function remains long after the wound has healed, as the result of a gap which persists between the retracted ends of a divided tendon, whether the original injury has been a subcutaneous rupture or an open wound, the parts should be exposed by a free

incision, the ends of the tendon-fragments freed from any new attachments, freshened, and, having been brought, if possible, into coaptation, sutured together. If the end of the proximal fragment cannot be found, or cannot be brought down to the distal fragment, the freshened end of the latter may be attached to a contiguous tendon, with the result of restoration of some power over the supplied part. If the matting of the end of the distal fragment in the cicatricial tissue at the point of injury is so extensive as to make its isolation unwise, the end of the proximal fragment may be brought down and likewise attached to the cicatrix, with the result of increasing the amount of voluntary control over the parts beyond.

WOUNDS OF NERVES.

While it is true that, in general, wounds of nerves should be treated on the same general principles as wounds of other structures, yet special attention is demanded to the methods and results of attempts at securing approximation of the divided ends in those cases in which important nerve-trunks are severed.

The researches of Waller as far back as 1852 demonstrated that following division of a nerve there early ensued degeneration in the peripheral segment, it being possible to detect the change as early as forty-eight hours after the injury, and the degeneration extending throughout the whole length of the segment. The myelin begins to disintegrate, and by the fourth to the sixth day has mainly disappeared, leaving the sheath of Schwann filled with fine, fatty granules; by the twentieth day the sheaths have become empty and the extreme degree of the degeneration has been reached, for after this time very little change occurs. A similar degeneration begins at the cut end of the proximal segment, but only extends as far as the first annular constriction or node of Ranvier. The axis cylinder is not affected, but after a varying interval begins to send out shoots, from one to three in number, covered with myelin, having very short interannular segments, which extend into the tissue of new formation which has cemented the nerve-stumps together, finally cross it and reach the tissue of the distal segment. The shorter the space between the divided nerve ends the more certain and rapid this process. The

younger and more vigorous the patient the less the probability of its failure. The regeneration of the distal segment now begins; the sheath of Schwann begins again to be filled with a granular substance which soon assumes the character of myelin, the axis cylinder reappears and the atrophied and shrunken cord gradually assumes the appearance and nearly the dimensions of the original nerve; pari passu with these changes return and increase of functional power appear; in the average case sensibility and motility begin to be appreciable in from three to four weeks; by the thirteenth week it is considerable, and by the end of perhaps eighteen months full restoration of function has been attained. The clinical history of cases of nerve-suture is quite in accord with these experimental observations. In the majority of cases in which function has returned it has become quite noticeable by the tenth or twelfth week. The process of recovery, once initiated, has continued over a long period. Sensibility is the first to return. A number of "paradoxical" cases have been reported in which, after suture, both in primary and secondary cases, return of function has occurred within a few days. It is presumable that in these cases anastomosing nerves have assumed the function of the injured nerve.

The higher up in its course a nerve-trunk is divided—that is to say, the more extensive the lower segment which must be regenerated—the more uncertain the result, the greater the liability to failure of functional restoration. Most of the instances of return of function after suture of nerves have been in cases of wounds of the nerves of the forearm. Less favorable results have followed in cases of wounds of the trunks in the axilla. Thus Etzold[1] reports six cases of such wounds sustained by students while duelling with swords. Of these, in four there was no restoration of function after periods varying from five months to six years. In a fifth case the median nerve alone was injured and a bridge of connective-tissue still held the stumps together. The paralysis was limited from the beginning and final restoration of physiological function took place. In the sixth case, involving division of all the motor trunks, after six months evidences of returning function began to be manifest, and after nine months the function of the triceps was well

[1] *Deutsche Zeitschrift für Chirurgie.* Bd. XXIX., p. 430.

marked and there was beginning ability to move the forearm. No case, however high up, should be deemed hopeless after the experience of Markoe,[1] who, in the case of a child of five years of age, after secondary suture of the superior trunk of the brachial plexus in the neck, done 131 days after division of the nerve, saw complete restoration of function within a year, although the first sign of returning function was not noticed until seven months after the suture was made. Return of function after suture of the sciatic nerve has been reported in a number of instances.

The regeneration of nerve-tissue through a cicatrix, and thus the spontaneous restoration of the function of a nerve that has been divided, even when considerable loss of substance, or retraction from each other of the divided ends has been present, has been observed to occur with sufficient frequency to render not altogether hopeless any recent case of paralysis resulting from section of a nerve; as a rule, however, the re-establishment of the functions of a nerve never takes place when its extremities have been allowed to become separately cicatrized; but in such cases an after-history of abolished function, neuralgic and trophic disturbances is entailed. When, however, the ends of the divided nerve can be brought into early apposition, and primary union of the wound can be secured, eventual restoration of function in great part may be reasonably counted upon. In less than twenty per cent. of reported cases has total failure occurred.

The indication is imperative, therefore, to secure and maintain the closest possible approximation of the cut surfaces of a divided nerve during the healing of the wound, that the amount of cicatricial tissue may be reduced to a minimum, and that the more speedy and certain restoration of function may be favored.

A degree of approximation may be secured by the position of the wounded part, by keeping it in such a position that the nerve-trunk shall be relaxed, and by those means of approximation which may be applied to secure coaptation of the surfaces of the wound in general; but the intrinsic retraction of the fragments of the nerve-trunk itself will still cause, in most instances, more or less of a gap to remain between them.

[1] Annals of Surgery, 1885, ii., 185.

In contused and lacerated wounds, and in wounds in which there is appreciable loss of substance, it is unlikely that even approximate apposition of the ends of divided nerves could be effected without the use of special means. The natural resource in such cases, in addition to the general means of relaxation and approximation already referred to, would be to isolate the separated ends of the nerve-fragments, draw them down into apposition with each other, and keep them apposed by suturing them together.

The knowledge of the evil effects frequently due to punctures of nerves and to their inclusion in ligatures, the fear of tetanus and of inflammatory complications, formerly rendered surgeons cautious in resorting to nerve-suture. A more frequent resort to it has, however, marked the practice of surgeons of late years; in none of the reported cases have untoward complications occurred, and the marked benefits secured by its practice have now established it as a regular surgical procedure, the neglect of which, in the cases calling for it, would be censurable. When a wound has been allowed to heal without suturing of a divided nerve, or if the suture has been used without return of function, a secondary suture should be attempted after exposure of the nerve above and below the seat of injury and excision of the cicatrix. Such secondary suture has been followed by restoration of function in a proportion of cases nearly as great as has the primary suture.

Application of the Nerve-suture.—For the purpose of securing apposition of the two ends of a cut nerve, sutures may be introduced either through the substance of the nerve-trunk itself or simply through the connective-tissue that acts as a sheath to the nerve, including, perhaps, the neurilemma. The former constitutes "direct nerve-suture," the latter "indirect" or "peri-neural" suture.

Direct Nerve-suture.—This is the form of suture which has been resorted to in the greater number of the published cases of nerve-suture. By means of a fine needle the thread is made to traverse the body of the nerve and embrace its substance in the knot which is tied. By some the nerve has been pierced through and through; others have brought out the thread at the lower or at the middle part of the cut surface. The latter method is more likely to secure accurate and steady coaptation, but if there is any strain upon the suture, it will be more quickly cut out.

In the former method greater care will be required to obtain exact adjustment and avoid angular deviation of the ends when the knot is tied, but it gives a greater security against subsequent gaping by retraction. One thread only will suffice, unless a large trunk, as the great sciatic, is under treatment.

Peri-neural Suture.—The insertion of the sutures through the perineural connective-tissue, when, by so doing, sufficient traction on the nerve-fragments can be effected to overcome the gaping at the point of division, recommends itself by the fact that by its practice the nerve-bundles neither receive injury by the needle puncture nor by the after-strain of the thread. For its application two sutures are required, one at either side of, and close to, the nerve. When the sutures are drawn up and carefully knotted, coaptation of the cut surfaces of the nerve may be obtained with even more accuracy than when the direct suture is employed. The results obtained by the use of the indirect suture have been very satisfactory.

Both the direct and indirect methods may be employed in the same case, when the conditions seem to require it, the one great indication to be met being exact and stable coaptation of the cut surfaces.

FIG. 105.—Splitting bulbous upper end of nerve for broader apposition and suture with lower end; secondary suture.

In cases of secondary suture, difficulty may be experienced in finding the nerve ends and in isolating them from the dense cicatricial tissue in which they are imbedded. Rather than groping in the altered tissues, it is better to extend the incision sufficiently to permit the exposure of the trunks in their unaltered position at a distance from the cicatrix, and thence trace them down into it. The upper end is usually the seat of some bulbous enlargement, the lower end is atrophied and degenerated; if they are united by cicatricial tissue this should be excised, the section of the upper segment being made high enough up to expose normal nerve tissue; as such tissue no longer exists in the lower segment, it is not to be sought for, and only the manifest cicatricial tissue cut away. A method of in-

creasing the surface available for apposition of the two segments is shown in Figure 105.

The Suture Material.—The choice of the thread for the suture is of importance, for the highest success of the suture can be obtained only by securing union by first intention. No material should be used for the suture which will interfere with primary union of the wound. Aseptic catgut or silk may be used, but the catgut is to be preferred, as by its subsequent spontaneous absorption it is not so likely to become a source of future irritation. With the use of catgut, and the indirect method of suture, no hesitancy need be felt in the application of the suture in every case of complete division of a nerve-trunk.

Conditions Requiring Nerve-suture.—A recent wound, in which a nerve-trunk has been severed, requires in all cases the separate suturing of the ends of the divided nerve, as one of the elements of securing proper "wound-apposition." No latitude of practice and judgment can be allowed even in cases in which the external wound is quite restricted, and in which little tendency to retraction may be supposed to exist, and it may appear possible that by position and the general measures instituted for the approximation of the wound-surfaces, primary union could be hoped for.

Even though the retraction of the divided ends of the nerve may not be great, the external wound should be enlarged, the nerve ends exposed and the suture applied.

When decided separation of the divided ends of the nerve exists, either as the result of retraction or of loss of substance, still less should the suture be omitted. The amount of separation which can be overcome, so that the ends of the nerve-fragments can be again apposed, may be considerable.

Nélaton brought together the ends of the median nerve after having exsected two and one-third inches of its continuity; von Langenbeck obtained union between fragments of the great sciatic nerve that had been separated by a distance of two inches. If, however, it is found impossible to bring the divided ends together, one of four expedients may be adopted. First, if several nerves have been divided, the expedient of Flourens may possibly be resorted to, that of uniting the lower end of the most important nerve to the upper end of another. Second, if such less

important nerve be not already divided, if it be accessible, sufficient portions of its surface may be freshened at two points convenient for the approximation of the ends of the wounded nerve, and these respective ends sutured thereto, virtually grafting it in. To this procedure Reed has given the name of Neural Infixation. A successful instance of this kind is reported by Marchand, from the clinic of Deprès. A lacerated wound of the left arm had torn the median nerve. Deprès found it impossible to bring the central end of the torn nerve down so as to suture it to its corresponding fragment. He therefore exposed the ulnar nerve, and having separated its fibres by tearing them apart with a pair of dressing forceps, into the interspaces inserted the fibres of the peripheral end of the median nerve. The procedure was crowned with success, and the patient recovered a useful hand.

The two remaining expedients are those of *"neuroplasty,"* or transplantation of nerve-tissue to fill the gap, and of *"tubular suture."* The transplantation of a piece of a nerve-trunk freshly removed from an amputated limb or from the body of a living animal to fill a gap in a resected nerve was first proposed by Gluck, of Berlin, who resected in chickens three or four centimetres (1 to 1½ inch) of the sciatic nerve, which he replaced by a piece of the sciatic nerve of a rabbit, sutured at both of its extremities. The chickens thus operated upon regained the power of walking as well as those upon which direct suture of the sciatic had been practised, while section of the sciatic without suture or autoplasty produced a paralysis of this nerve which was still complete at the end of ten weeks. Roberts[1] refers to thirteen cases, gathered from literature, in which neuroplasty has been resorted to in man. In four of these cases both the motor and the sensory function is definitely stated to have been regained; in two satisfactory recovery is reported, details not given; in one improvement in sensation, with no corresponding improvement in motion resulted; in four improved sensation, without mention as to the motor function, is reported. In one the result is unqualifiedly unsatisfactory. While these cases are an encouragement to further attempts in this line, our knowledge of the processes of degeneration and repair in nerve-tissue separated from its central connection is sufficient to indi-

[1] Dennis' System of Surgery, ii., 898.

cate that the part which such a graft plays is simply to supply a quality of tissue, bridging over the gap, favorable for the growth into it and through it of the axis cylinder buds of the proximal segment, until guided by it they reach the distal segment.

Tubular suture, also suggested by Gluck, has also as its object the guiding of the advancing axis cylinder shoots from the central to the distal segment. A decalcified bone tube of sufficient length is first drawn over one of the nerve segments, isolated as far as necessary to admit of this being done; then, after the nerve ends have been brought as near together as possible by catgut sutures, the tube is slipped along until the two nerve ends and the intervening catgut threads are enclosed in the tube. The wound is then closed. Gluck only obtained negative results, but Vaulair[1] has seen, he says, after a delay of four months, the regeneration of a nerve-trunk measuring five centimetres (2 inches).

To facilitate approximation of the divided ends of a nerve, otherwise impracticable, it would be possible to shorten up a limb by resection of sufficient amount of the shaft of the bone or bones thereof (Löbker).

When the section of the nerve is the result of a contused wound, the disintegrated or badly contused portions of the exposed ends should be resected until surfaces capable of primary adhesion are reached, which are then to be brought together. In cases of severe contusion of a nerve-trunk, without actual solution of its continuity, the propriety of exsecting the contused portions, and suturing the extremities which remain, is worthy of consideration in view of the frequent, prolonged, and severe loss or disturbance of function following nerve-contusions, and the good results obtained by nerve-suture.

The suture is contra-indicated when the wound is no longer recent, but has begun to suppurate. In such cases, general measures of approximation must alone be relied on until cicatrization has taken place, after which secondary suture should be done.

The approximation and suturing together of the divided ends of a nerve should be done as early as possible after the wound has been inflicted. It is important that primary union be secured; minute observ-

[1] Nicaise, Injuries and Diseases of Nerves. International Encyclopædia of Surgery, vol. iii., p. 624.

ance of every requirement of wound-treatment should mark the care of a wound involving a nerve-trunk.

Immobilization by splints so applied as to keep the parts at rest in such position as will prevent tension upon the sutured nerve is vital to the success of nerve-suture. The splint should be kept in place for at least three weeks. Upon the removal of the splint systematic treatment to the paralyzed muscles must be instituted; massage, passive motions, stimulation with the Faradic current, constitute the means available for this purpose. They are to be persevered in until by the restoration of normal innervation the nutrition of the muscular tissue is provided for.

CHAPTER XVII.

WOUNDS OF BLOOD-VESSELS.

Importance of Wounds of Blood-vessels—Results to be Secured in Treatment—Difficulties—Obliteration of Vessels—Relations of Coagulum to Repair—Physiology of Repair—Apposition of Inner Serous Surfaces—Means of Compression—The Ligature—Ligation—Rules of Procedure—End-to-end Suture of Large Arteries—*Complications of Wounds of Blood-vessels*—Primary Hæmorrhage—Intermediary Hæmorrhage—Secondary Hæmorrhage—Diffuse Traumatic Aneurism—*Wounds of Veins*—Peculiarities—Phlebitis and Periphlebitis—Thrombosis—Effects of Septic Ligatures—Acupressure and Forcipressure—Advantages of Aseptic Ligatures—Repair of Vein Wounds—Lateral Ligation—Braun's Statistics—Necessary Precautions—Lateral Suture.

ALL wounds involve wounds of blood-vessels, and the indications for treatment which the resulting hæmorrhage presents have claimed attention in connection with each of the general classes of wounds that have been considered. There remain, however, certain special considerations with regard to wounds of these organs to which further examination should be directed.

It is impossible to exaggerate the importance of wounds of blood-vessels; the treatment which is demanded, when vessels of any size are involved, must be instantaneously applied, in default of which quick death is inevitable. It is the opinion of Lidell[1] that more lives are lost from the hæmorrhage resulting from wounds of blood-vessels, either directly or indirectly, than from all the other consequences combined which flow from wounds. In support of this assertion he states that of the slain in battle, of whom he had personal observation during our War of the Rebellion, a very large share, about one-half, possibly even more than that, perished by hæmorrhage from wounds of the large blood-vessels of the neck, chest, abdomen, groin, etc., or from wounds involving vital

[1] Injuries of Blood-vessels. International Encyclopædia of Surgery, vol. iii., p. 46.

organs like the brain and lungs, the bleeding whereof caused deadly compression of these organs before succor could be afforded.

The treatment, again, must be effectual for the permanent obliteration of the open orifices in the wounded vessel, otherwise renewed peril from the escape of blood will supervene.

The treatment of the wounded vessel should, if possible, be conducted in such a way as to avoid introducing sources of disturbance into the healing of the other wounded tissues; thereby, also, its own undisturbed repair will the most certainly be secured. The elements of treatment which wounded blood-vessels require do not differ from those required by other tissues. Hæmorrhage must be arrested, the wound must be cleansed and brought into apposition, protection against disturbance from without must be supplied, and rest must be secured until repair is perfected.

The practical difficulties which complicate the treatment of these wounds spring from the peculiar function and anatomical character of the organ. The blood-pressure within them is a constant force tending to separate the edges of the wound, while the escape of this vital fluid constitutes a danger which must be prevented at the sacrifice, if necessary, of the functional activity of the organ itself. The thin walls of the organ do not afford sufficient surface, when wounded, for securing perfect and reliable apposition of the edges of the wound, in antagonism to the pressure of the column of blood which they enclose, and to the intrinsic tendency to gaping from the contractility of its own tissue. Longitudinal wounds of veins, however, in many instances form an exception to this statement. The readiness with which the internal tunic of blood-vessels responds to irritation by the production upon its surface of plastic material, suffices, when taken advantage of, to supplement the reparative deficiencies of the cut surfaces. From this source granulation tissue is produced that by its organization obliterates that part of the vessel filled by it, and permits the undisturbed organization of the reparative material produced from the wound-surfaces themselves. The coagulum which forms within the last portion of the canal of a severed vessel, and blocks it up, not only serves as a temporary plug to prevent the escape of blood, but it stimulates the vascular tunic, with which it is in contact, to an increased cell-activity that results in new tissue that not only assists in forming a permanent seal to the vessel, but also invading the clot,

substitutes for it cicatricial tissue that converts the now unused portion of the vessel into a fibrous cord. The result is a total loss to the economy of a portion of its substance, and the permanent impairment of function of an organ. The importance of this loss and impairment will depend upon the importance of the particular vessel and upon the ability of other vessels to supplement the defects of the injured one by increased development and labor. Permanent impairment of function, œdema, and gangrene are not infrequent results of the obliteration of vascular trunks.

The presence of a coagulum, however, is not essential to the inauguration of the process by which a wounded vessel is to be sealed up, and its presence is an embarrassment, rather, to the repair when the needful support and rest to the part can be secured while its repair is in progress. The effects of the original traumatism by which the vessel has been wounded suffice to stimulate that portion of the internal tunic adjacent to the wound to the needed nutritive activity, and if the effort of the surgeon is successful in keeping the proliferating surfaces of this tunic in contact until firm adhesion has taken place by the organization of the new material supplied by it, the best result will be obtained.

Apposition of the wound-surfaces, therefore, in the case of wounds of the blood-vessels, with exceptions that will be mentioned, should be substituted by apposition of the surfaces of that part of the inner tunic of the vessels which is immediately adjacent to the wound.

The treatment of wounded blood-vessels in this respect involves the same principles as those which hereafter will be found to govern the treatment of wounds of thin-walled membranous organs, as the pericardium, alimentary canal, or urinary bladder, the walls of which present on one side a serous surface, the apposition of which, rather than of the wound edges themselves, affords the most rapid and secure means of closing a penetrating wound of their substance.

Some means of compression will be required in every case for keeping the inner surfaces of the vessel in contact until firm adhesion, adhesion firm enough to resist the impulse of the blood-current, and the tendency to gape of the walls of the vessel itself, has taken place. This will be afforded by the means which have at once been adopted for restraining the escape of blood. The various resources which are at the command of the surgeon for this purpose have already been considered at length in the

chapter devoted to arrest of hæmorrhage (Chapter VII.). Whatever method, however, may have necessarily been adopted in the emergency of the primary hæmorrhage, if the wounded vessel prove to be of a size that its prolonged compression is necessary, it should be substituted, at the earliest practicable moment, by the application of an aseptic ligature.

The ligature discharges two functions, that of a means of hæmostasis and of apposition. In its application for the first purpose, it is essential that it should be drawn with such tightness that its grasp of the vessel shall be so firm that it shall not slip off accidentally. It is not necessary, however, that it should rupture any of the coats of the vessel, or that the distal portion of the vessel should be strangulated.

The purposes of apposition require a force of ligation no more powerful than the preceding. The additional traumatism of ruptured coats is not required for exciting or reinforcing the reparative effort, while such application of a ligature as shall determine a process of ulcerative inflammation in the tissues grasped by it, is to be deprecated as the possible determining cause of secondary hæmorrhage.

The tying a ligature should be effected by firm and steady tension on the ligating thread. If the vessel has been isolated so that it alone is grasped in the loop of the ligature, the force required to properly tie it is not so great but that a comparatively weak thread can be used; unnecessary force, so that the inconvenience of breaking the thread frequently results, is often used. If some of the surrounding tissue is also grasped by the ligature, *ligature en masse*, greater primary force must be used to lessen the results of the later cutting of the tissues by the compression of the ligature and the possible loosening of the ligature itself.

It is important, as the first step in the treatment of a wounded blood-vessel—it being understood that in all cases vessels whose size or relations are such as to require special treatment are being referred to—that full exposure of the wound in the vessel is secured. In the case of superficial wounds, and of deeper wounds with extensive division of the more superficial structures, such exposure of a wounded vessel is easily and spontaneously accomplished. In deep wounds, with restricted external wound, as in punctured and gunshot wounds, this full exposure of the wounded vessel is equally imperative. Plugging of such a wound with tampons, or compression of the main trunk on its cardiac side, if it be an

artery, may be resorted to as means of temporary arrest of bleeding; but as soon as the conditions permit the methodical dressing of the wound, the vessel must be laid bare at the injured point, and permanent ligation be practised. For this purpose free incisions must be made through the skin and overlying tissues, always making them of sufficient length so that the structures at the bottom of the resulting wound shall be distinctly exposed and readily accessible to manipulation.

Care to first render the limb bloodless, in the case of wounds of vessels of the extremities, by the use of an elastic bandage, after the method of Esmarch, will greatly facilitate the making of the required incisions. In other cases, a finger thrust into the wound so as to reach and compress the wound in the vessel, or the temporary application of a clamp-forceps, will both control the hæmorrhage for the time being, and will serve as an invaluable guide for the incisions. As the incisions are made, all blood-clots should be thoroughly and carefully removed by sponging and scraping, and perfect cleansing of the wound from fluid blood and débris of every kind should be done. When the wound in the vessel has been found and exposed sufficiently to enable its entire extent to be seen, the vessel must be isolated, and a ligature applied to a healthy part of it both above and below the wound. The ligatures must be aseptic—catgut or silk—and after having been securely tied, should be cut off close. If, by misfortune, no aseptic material for ligatures can be obtained, necessity will compel the use of an ordinary thread. In this case, one end having been cut off near the knot, the other should be brought out at the most dependent angle of the wound.

Should difficulty be experienced in distinguishing veins, when bloodless and collapsed, the elastic bandage may be slackened sufficiently to permit the blood to pass through the arteries while its current through the veins is still interrupted. By this means the venous trunks become distended and appreciable, or if the vein is wounded the blood escapes from it.

If the vessel have been only partially divided by the original injury, after the ligatures have been applied on either side of the wound, the division should be made complete, and the two ends allowed to retract.

The direction to apply a ligature to the distal as well as the proximal side of a vessel-wound is especially applicable to wounds of arteries, and is

to be observed whether the distal extremity bleeds when exposed or not. If left unsecured, imminent risk is incurred from intermediary hæmorrhage as the full natural force of the circulation begins to be again felt, or from secondary hæmorrhage after a more free collateral circulation shall have become established.

The same reasons contra-indicate the practice of ligating the trunk of the artery above the wound, except in those instances in which the bleeding artery is inaccessible, as the internal maxillary, and, in some instances, the lingual.

That the continuity of a wounded large-sized arterial trunk may be

FIG. 106.—End-to-end suture of femoral artery (*Murphy*).

preserved has recently been demonstrated by Murphy[1] in the case of perforation of the common femoral artery by a pistol-bullet, which also perforated the femoral vein just above the junction of the profunda. The artery was temporarily secured by clamps, while the wound in the vein was sutured, the suturing diminishing the calibre of the vein to about one-third its normal diameter. Two inches of the artery were then exposed and freed from all attachments, and half an inch of its continuity resected, including the wound opening (Figure 106). The proximal end

[1] Medical Record, Jan. 16, 1897.

was deprived of its adventitia for a third of an inch, and then invaginated into the distal end to that extent by four double-needled threads, which penetrated all the walls of the artery. A row of sutures was placed around the overlapping distal end, the sutures penetrating only the media of the proximal portion. The adventitia was then drawn down over the line of union and sutured, and the clamps were removed. Not a drop of blood escaped at the line of suture, and pulsation was immediately restored in the vessels below. Satisfactory healing followed.

In the treatment of wounds of small vessels lying at the bottom of deep cavities, and, in more superficial wounds, where a general bleeding from many small vessels persists, in which the application of ligatures is impracticable, the methods which have been described are impracticable, and the use of the actual cautery and of tampons is necessitated.

Every effort should be made to secure primary union in wounds that are complicated by wounds of important blood-vessels. The greatest safeguard against the occurrence of secondary dangers from wounds of the vessels is secured by preventing disturbances in the healing of the general wounds of which they form a part. Every precaution against sepsis which is within the command of the surgeon should be practised in the dressing and after-treatment of these wounds.

COMPLICATIONS OF WOUNDS OF BLOOD-VESSELS.

The complications which are so especially related to wounds of vessels as to demand consideration here are the losses of blood which are liable to attend these wounds. Those losses which follow immediately upon the infliction of the injury constitute *primary hæmorrhage;* those which attend the period of reaction constitute *intermediary hæmorrhage;* and those which take place after the establishment of suppuration constitute *secondary hæmorrhage.* The extensive effusions of blood which follow upon the subcutaneous rupture of large blood-vessels, known as *traumatic aneurisms,* demand, also, some consideration.

Primary Hæmorrhage.—The treatment demanded for the control of this complication has been fully considered in the first part of this treatise, Chapter VII., to which reference should be made.

Intermediary Hæmorrhage.—The treatment of intermediary

hæmorrhage must be conducted on the same principles as those which guide the treatment of primary hæmorrhage. Its occurrence is an evidence of the inefficiency of the means which had been previously instituted, and would hardly take place in any case if the directions which have been given for the full exposure of wounded vessels, their careful ligation in a sound part of their structure on either side of the wound, the complete division of the vessel, if previously but partially divided, and the removal of coagula and débris from the wound, have been followed. It is impossible to dwell with too much stress upon the importance of care and thoroughness in the application of the first dressing as a preventive of subsequent complications. This is illustrated by the list of causes of intermediary hæmorrhage which the medical historian of the War of the Rebellion gives as discernible in the cases, seventy-seven in number, which appear in the records of the Surgeon-General's office of the army.[1] The report states that "the earlier cases of hæmorrhage were due to the force of the blood-current in the returning circulation during reaction; to commencing inflammatory action, in which the swelling had been sufficient to force out the protective coagulum; to weakened arterial walls, and to a depraved condition of the blood in persons suffering from exhausting or depressing diseases. Not unfrequently the hæmorrhage of the earlier days had its source in the injury of some vessel of considerable size, unnoticed in the primary examination of the wound. Cases have been cited in which no excessive hæmorrhage was noticed until attempts were made to effect the removal of a lodged missile or foreign body, which had prevented bleeding by acting as a plug or tampon." The first three causes in this list are the results of failures to primarily expose and ligate the vessels. The last two to want of thoroughness in the primary examination of the wound. Other frequent causes of intermediary hæmorrhage, such as the inability of the vessel to retract by reason of its incomplete division, the imperfect compression of the vessel by a large coagulum which has been permitted to accumulate over it, acting the rather as a poultice upon it to keep it relaxed, and disturbance of the parts by muscular

[1] Medical and Surgical History of the War of the Rebellion. Part Third, volume ii., Surgical History, p. 809.

spasm, motion, or external traumatism, all alike are examples of infractions of the primary principles of wound-treatment.

The occurrence of intermediary hæmorrhage demands at once a new dressing of the wound, *ab initio*. It must be opened, enlarged if necessary, cleansed, explored, the vessels secured as already described, and its primary dressing and after-treatment conducted scrupulously in accordance with the general principles and methods of wound-treatment already described.

Ligation of the main trunk, the use of the actual cautery and the tampon are resources to be used in conditions noted on a previous page in this chapter.

SECONDARY HÆMORRHAGE.—Under this head are to be embraced all losses of blood from wounded vessels occurring after the establishment of suppuration. Referring again to the "Medical and Surgical History of the War of the Rebellion" (*loc. cit.*), we find the statement that by far the greater number of cases of secondary hæmorrhage are due to the separation of a slough, the result of a contusion of the walls of the vessel and the inflammatory action consequent upon it. Identical in nature with this class of cases is that group in which the hæmorrhage takes place where the ulceration of the vascular coats, produced by the constriction of an irritating ligature, is accomplished, without the previous obliteration of the adjacent portion of the vessel by adhesive inflammation.

Yet other cases have their origin in the breaking down of adhesions, or the progressive ulceration of tissue due to the changes effected in the wound by destructive septic processes.

Neglect to secure, by ligature, the distal orifice of a severed vessel may be the cause of a later hæmorrhage, after the collateral circulation shall have become sufficiently free to restore the strength of the blood-current in that portion of the vessel.

Faulty application of the ligature in the primary dressing; subsequent increase of blood-pressure as the result of venous thrombosis, or inflammatory engorgement, or improper position of the wounded part; interference with repair by muscular spasm, motion, or external traumatism; constitutional conditions that interfere with repair—these should be added to the list of causes that may determine a secondary hæmorrhage.

organs like the brain and lungs, the bleeding whereof caused deadly compression of these organs before succor could be afforded.

The treatment, again, must be effectual for the permanent obliteration of the open orifices in the wounded vessel, otherwise renewed peril from the escape of blood will supervene.

The treatment of the wounded vessel should, if possible, be conducted in such a way as to avoid introducing sources of disturbance into the healing of the other wounded tissues; thereby, also, its own undisturbed repair will the most certainly be secured. The elements of treatment which wounded blood-vessels require do not differ from those required by other tissues. Hæmorrhage must be arrested, the wound must be cleansed and brought into apposition, protection against disturbance from without must be supplied, and rest must be secured until repair is perfected.

The practical difficulties which complicate the treatment of these wounds spring from the peculiar function and anatomical character of the organ. The blood-pressure within them is a constant force tending to separate the edges of the wound, while the escape of this vital fluid constitutes a danger which must be prevented at the sacrifice, if necessary, of the functional activity of the organ itself. The thin walls of the organ do not afford sufficient surface, when wounded, for securing perfect and reliable apposition of the edges of the wound, in antagonism to the pressure of the column of blood which they enclose, and to the intrinsic tendency to gaping from the contractility of its own tissue. Longitudinal wounds of veins, however, in many instances form an exception to this statement. The readiness with which the internal tunic of blood-vessels responds to irritation by the production upon its surface of plastic material, suffices, when taken advantage of, to supplement the reparative deficiencies of the cut surfaces. From this source granulation tissue is produced that by its organization obliterates that part of the vessel filled by it, and permits the undisturbed organization of the reparative material produced from the wound-surfaces themselves. The coagulum which forms within the last portion of the canal of a severed vessel, and blocks it up, not only serves as a temporary plug to prevent the escape of blood, but it stimulates the vascular tunic, with which it is in contact, to an increased cell-activity that results in new tissue that not only assists in forming a permanent seal to the vessel, but also invading the clot,

substitutes for it cicatricial tissue that converts the now unused portion of the vessel into a fibrous cord. The result is a total loss to the economy of a portion of its substance, and the permanent impairment of function of an organ. The importance of this loss and impairment will depend upon the importance of the particular vessel and upon the ability of other vessels to supplement the defects of the injured one by increased development and labor. Permanent impairment of function, œdema, and gangrene are not infrequent results of the obliteration of vascular trunks.

The presence of a coagulum, however, is not essential to the inauguration of the process by which a wounded vessel is to be sealed up, and its presence is an embarrassment, rather, to the repair when the needful support and rest to the part can be secured while its repair is in progress. The effects of the original traumatism by which the vessel has been wounded suffice to stimulate that portion of the internal tunic adjacent to the wound to the needed nutritive activity, and if the effort of the surgeon is successful in keeping the proliferating surfaces of this tunic in contact until firm adhesion has taken place by the organization of the new material supplied by it, the best result will be obtained.

Apposition of the wound-surfaces, therefore, in the case of wounds of the blood-vessels, with exceptions that will be mentioned, should be substituted by apposition of the surfaces of that part of the inner tunic of the vessels which is immediately adjacent to the wound.

The treatment of wounded blood-vessels in this respect involves the same principles as those which hereafter will be found to govern the treatment of wounds of thin-walled membranous organs, as the pericardium, alimentary canal, or urinary bladder, the walls of which present on one side a serous surface, the apposition of which, rather than of the wound edges themselves, affords the most rapid and secure means of closing a penetrating wound of their substance.

Some means of compression will be required in every case for keeping the inner surfaces of the vessel in contact until firm adhesion, adhesion firm enough to resist the impulse of the blood-current, and the tendency to gape of the walls of the vessel itself, has taken place. This will be afforded by the means which have at once been adopted for restraining the escape of blood. The various resources which are at the command of the surgeon for this purpose have already been considered at length in the

Veins," which was published in 1811, seems to have been the first to draw special attention to the dangers attending injuries of veins. He speaks of the "fatal catalogue of tied veins," and says that he has observed something like that superstitious alarm which is excited by events that we do not expect and cannot explain, when such a catalogue is compared with the generally successful cases of tied arteries. In the period immediately preceding the time when Travers wrote, there had been an entire absence of apprehension of danger in dealing with veins, so that, in the language of that writer, they were attacked with singular rudeness, pricking, cutting, tying, and burning them, without ever adverting to any other than the mechanical effects of such operations upon the diseases for which they were instituted.

This author was successful in awakening attention to the fact that disastrous inflammatory complications often followed injuries of veins; that they sometimes followed a puncture, sometimes a division, a ligature encircling the tube, or including only a part of it; or that they sometimes arose spontaneously from an inflamed surface, of which the vein formed a part. The practice of phlebotomy, though involving only a simple longitudinal wound of a superficial vein, by the great frequency with which it was performed, afforded many examples of the accidents that might follow such wounds. Every year witnessed fatal inflammatory complications supervening upon phlebotomy. By many surgeons veins came to be regarded as vessels especially intolerant of interference, and prone to the development of unexpected and uncontrollable complications. Ligation of veins, in particular, became considered as hazardous. Many of the surgical writers of the second quarter of the present century taught that it was attended with great danger, and to be avoided by all possible means. Dupuytren[1] spoke of phlebitis as "that inflammation so grave, so difficult to master, which has caused so great a number of persons to perish whose veins have been ligated." Chassaignac[2] taught that ligation was one of the most dangerous operations of surgery, and more recently, Erichsen,[3] that the application of a ligature to a vein "should, if possible, always be avoided."

[1] *Leçons Orales de Clinique Chirurgicale*, 1839, t. iii., p. 251.

[2] *Traité Clinique et Pratique des Operations Chirurgicales*, t. i.

[3] Science and Art of Surgery, 1878, vol. i., p. 278.

A numerical majority of surgeons, however, have always held that the dangers of the ligation of veins were not sufficiently imminent to prevent its adoption as a measure of convenience in the treatment of a wound. No difference of opinion has existed, however, as to the hazards attending the ligation of veins whose tunics were diseased, as in the case of varicose veins.

Thrombosis and suppurative peri-phlebitis were observed to be particularly likely to be provoked in instances in which veins were contused or denuded. In three instances, one surgeon—Ollier, of Lyons—is reported[1] to have seen death follow in from eighteen to thirty-six hours after the beginning of a thrombosis complicating a wound of this character. From this experience he concluded that extensive denudation of a vein was more dangerous than ligation; and that in cases in which immediate union was not obtained after such denudation, when sloughing of the flaps that cover the veins occurs, when, in a word, the veins remain exposed at the bottom of a suppurating wound, all the accidents of an extensive and progressive thrombosis were likely to occur. These complications, however, are not the inevitable consequences of denudation and contusion, for such injuries, in the greater number of instances, progress to recovery without their development. These observations, however, all refer to the preantiseptic period of surgery. All the dangers and difficulties supposed to attach to surgical manipulations of the veins have vanished with the adoption of adequate cares to prevent the introduction or the unchecked progress of sepsis in wounds.

Physiological experiment has fully demonstrated that the tunics of a vein do not possess a special intolerance that renders them liable to destructive inflammation more quickly and upon less irritation than other tissues. The more frequent connection of wounds of veins, than of their companion vessels, the arteries, with diffuse suppurative inflammations and profound and rapid general intoxication, is not a myth, nevertheless. It results from the readiness with which the connective-tissue that ensheathes the veins permits the progressive invasion of micro-organisms, and from the fact that the resulting peri-phlebitis determines the formation of coagula in the involved vein, which, in their turn, are likely to be

[1] Nicaise: *Des Plaies et de la Ligature des Veines*, 1872, p. 42.

speedily invaded by micro-organisms, and thus become converted into poison-depôts, from which ptomaines, pus, and emboli are discharged directly into the circulation.

These dangers require to be considered, and to engage the careful effort of the surgeon for their prevention in all cases of wounds of veins.

The effect of the constriction of a vein by a ligature does not introduce any new danger into a wound. The evil effects which have been noted as prone to occur in wounds in which ligation of a vein has been performed, arise only in those cases in which the material of the ligature is irritating, and is so applied as to become the means of the introduction or retention of septic matter in the wound. Whenever an ordinary unsterilized ligature is applied, the constricting thread is an irritating foreign body in the wound, and invariably excites along its track an inflammation which persists until its removal is permitted by the division, by ulceration, of the walls of the constricted vein—a period of time extending upon an average from one to two weeks, according to the size of the vein. Union by first intention is thus prevented, along the track of the ligature at least. The thread, saturated with the secretions of the suppurating sinus which it has created, becomes a medium for transmitting further sepsis to the deepest part of the wound. The irritation of its presence puts an additional strain upon the resisting power of the tissues among which it lies, and to this extent lessens their ability to resist invasion when septic organisms find access to the wound.

The natural resisting power of the tissues is sufficient to limit, in the great majority of cases, the amount of disturbances resulting from an ordinary ligature to a circumscribed inflammation, which simply mats together the tissues adjacent to the ligature, and confines the destructive processes to necrosis of the tissue grasped in the loop of the thread. But in cases in which original defective resisting power exists, as notably in tissues whose nutrition has been interfered with by the varicosity of their veins, and in those in which some general cachexia pre-exists, an unchecked diffusion of the disturbances introduced by such a ligature would be likely to take place.

These considerations, as to the sources of the disturbances which have been observed to complicate vein-wounds, show the importance of eliminating them, not only in cases where veins already diseased exist, but also

in all cases in which vein-wounds demand special means for the control of hæmorrhage and the maintenance of the walls in apposition. They justify the dread of ligation which was felt by many surgeons, when practised, as it was, with an infected thread, and they emphasize the importance of employing sterile absorbable ligatures, so that full compliance with the requirements of surgical cleanliness and of wound-protection may be accomplished in the treatment of this class of wounds.

Acupressure and forcipressure both present great advantages over the common ligature as methods for controlling venous hæmorrhages, and often one or other of them may be substituted for the ligature. The retention of the compressing needle or forceps is rarely necessary for a longer period than a few hours. Their smooth metallic surfaces do not irritate the wound; they may be enclosed in the protective material used for dressing the wound; and their early withdrawal removes the mechanical obstacles to primary union that they cause during their residence in the wound.

Forcipressure is especially available as a means of controlling bleeding from, and securing healing of small wounds in large venous trunks; the small opening, and more or less of the surrounding vein-wall, is nipped by the jaws of the forceps, without the lumen of the vessel being wholly occluded. At the end of from forty-eight to seventy-two hours, if the forceps are removed, the portions of the vein-wall gripped by it will have become adherent to each other by plastic deposit, which progresses to full organization and perfect healing of the vein-wound. In this manner I have controlled with success wounds of the internal jugular, the subclavian, the internal iliac, and the femoral veins.

In general, however, a more excellent way still is available to the surgeon in dealing with wounded veins. For, as acupressure needles and hæmostatic forceps excel the ordinary ligatures, so they, in turn, are excelled by the aseptic animal ligature and sterile protective dressings, by which, with a perfect hæmostatic, easily and universally applicable, that provokes no irritation by its presence in the tissues, and that is spontaneously removed by absorption when no longer needed, security is also guaranteed against the access from without of agencies that might disturb repair. By the use of such an aseptic ligature, it becomes possible to avoid the sources of disturbance that have thus far been recognized in

wounds of veins, and to make the application of a ligature safe in all cases.

For the purpose of obtaining more definite data upon which to base the employment of the ligature in treating vein-wounds, I made a number of experiments during the year 1882 upon goats, using aseptic catgut. My experiments included three ligations of the internal jugular vein, and two of the femoral vein.[1] Union by first intention of the operation wound was secured in each instance. As the result of these operations I secured specimens illustrating the condition of repair upon the second, fourth, ninth, fourteenth, and twenty-fourth days after ligation. Examination of them demonstrated that marked proliferation of the tissue-cells of the tunica interna had been excited, the activity of this proliferation being greater as the point where the vein walls were constricted and approximated by the ligature was approached. The accumulation and confluence of the mass of cells in the cul-de-sac formed by the vein-constriction, the subsequent extension of capillaries into them, and the consequent conversion of the new tissue into connective-tissue, were the successive steps by which permanent closure of the tied veins was effected. In none of these experiments did a thrombus form on either side of the ligature, except in one case, in which special effort was made to secure one by applying a second ligature to the vein, swollen with blood, a little more than an inch above the first one. The part of the vein between the two ligatures having been left filled with blood, a thrombus was thus obtained. The specimen was removed on the ninth day. In this case the clot was found to have simply mechanically distended the tunics of the vessel, making the study of the conditions presented by the tunics more easy, but not modifying the character of the reparative process. It was an unirritating injection-mass that was awaiting to be invaded and appropriated by active cells from the adjacent tissue.

The reparative changes which had been provoked by the application of the ligature may be regarded as having had, as their first object, the restoration of function in parts whose nutrition had been disturbed by the original application of the ligature. But the agent which had dis-

[1] The Use of Ligatures in Wounds of Veins. Medical News, Phila., 1883, xlii., 278.

turbed the nutrition of the tunica interna, and provoked a more active metamorphosis and proliferation of its cell-elements, had at the same time held the vein-walls in coaptation until the confluent plastic material formed had become sufficient in amount and tenacity to permanently unite them together. Essentially the process is that of the formation of a cicatrix, and in its course the ligature plays the same part as does the suture in ordinary wounds—that of maintaining coaptation until firm adhesion is secured. There may be seen in this, also, the same process as that by which a simple longitudinal slit in a vein-wall may be repaired without obstruction to the current of blood through the vessel, the edges of the slit themselves furnishing the material for its repair, the amount of which material, if only further irritation or traumatism be withheld, being strictly limited to the reparative needs of the injured structures.

LATERAL LIGATION.

The considerations which have been described, as to the process of repair after ligation of veins with unirritating ligatures, find an important practical application in determining the propriety of substituting a lateral ligature, or a lateral suture, for ligatures encircling the entire vessel in the treatment of wounds involving but a portion of the wall of a great vein.

The use of lateral ligatures has been strongly condemned by many surgical writers. Malgaigne[1] said, "the lateral ligature will be an operation always to be condemned," and that "for very extensive wounds of venous trunks, where compression is insufficient, the only resource is the ordinary ligature." The objection of this author was founded on the erroneous belief that permanent hæmostasis after a vein-wound depended upon the formation of a clot sufficient to occlude the entire lumen of the wounded vessel. Inasmuch, therefore, as the lateral ligature in some cases might fail to provoke the formation of such a clot when the ligature should come away, in such cases secondary hæmorrhage would be inevitable. The objection of all surgeons who have rejected this measure as a

[1] *Médecine Operatoire*, ed. 1861, p. 114.

justifiable proceeding has arisen from the frequency with which secondary hæmorrhage has occurred in the cases in which it has been employed.

Braun[1] compiled from published records twenty-four cases in which a lateral ligature was applied, and three cases of lateral forcipressure. Of these nine died from pyæmia and from secondary hæmorrhage. In one case the ligature slipped, and the hæmorrhage had to be controlled by other means. In thirteen of these cases, the internal jugular vein was the vessel wounded. Lateral ligature was applied in twelve instances, and forcipressure in one. Three deaths resulted from secondary hæmorrhage. In seven instances the femoral vein was involved. Lateral ligature was applied in five cases, the forcipressure in two. There was one death from secondary hæmorrhage, caused by the slipping off of the ligature, and five deaths from pyæmia. Five cases in which the axillary vein, one in which the subclavian, and one in which the external jugular were involved, all recovered.

The deaths from pyæmia were all due to septic hospital influences, and are not to be attributed in any way to the special method of ligation adopted. The proportion of cases of secondary hæmorrhage, however, is so great that, unless the danger of such a complication can be shown to be avoidable, the practice must be condemned, since its dangers outweigh any advantages that might otherwise attach to it.

These disasters, however, occurred in connection with the use of infected ligatures, the dangers of which, even for use in ligations of the whole circumference of a vein, have been dwelt upon, and such use deprecated. Much more imminent is the danger which their use entails when applied to the side of a vein. In many cases, as Malgaigne feared, no clot formed to act as a plug to the hole in the vein produced by the separation of the slough grasped in the loop of the ligature, nor did a sufficient amount of plastic exudate gather on the interior of the pucker, at the site of the ligature, to substitute a wall of new tissue for that carried away by the slough. Secondary hæmorrhage, in such cases, was inevitable. Lateral ligation, therefore, should not be employed when the surgeon must make use of an ordinary non-sterilized thread for his ligature. In

[1] *Ueber den seitlichen Verschluss von Venenwunden. Archiv für klinische Chirurgie*, 1882, xxviii., 654-672.

such cases the entire vessel must be included in the ligature, which must be applied both above and below the wound, and complete division of the vessel between the ligatures be done.

The use of aseptic materials for ligatures, which may be cut short, and over which speedy union of the entire wound by first intention may, with much certainty, be secured, places the subject of lateral ligature upon an entirely different basis. Care is first necessary that the ligature is securely applied, lest the accident of its slipping off should expose to disaster. Then the rent in the wall is virtually transformed into an extravascular injury, and the tissues of the puckered wall of the vein, in the grasp of the ligature, are placed in the same condition as that which characterizes veins when ligated in their whole circumference. No thrombus is required, nor formed, by its insufficiency or its disintegration, to become a source of danger. There is no ulcerative process to extend unduly, and to leave an opening in the vein-wall when the ligature comes away. That the process of the exudation and complete organization of the plastic material that fills in and effaces the irregularity produced by the application of the ligature should proceed undisturbed to its conclusion, demands, simply, that the general precautions for securing wound-repair be observed. The ligature acts as an unirritating reinforcement that prevents the rupture of this new tissue during the yielding period of its history, and itself is finally disintegrated, and is removed in the course of the ordinary tissue changes of the part.

Practised with sterile materials—catgut or silk—with aseptic precautions, lateral ligature is a safe and valuable means of treatment in wounds of the lateral walls of veins. It should especially be employed in the case of wounds of the main veins at the roots of the extremities, as the axillary, subclavian, and femoral, the complete closure of which would be likely to seriously disorder the circulation of the limb of whose blood it is the channel of return to the heart.

LATERAL SUTURE.

The application of a suture suggests itself as a resource in lateral wounds of large veins, when such wounds are too long or extensive to ad-

mit of being closed by a lateral ligature. Cheyne relates[1] the following case, in which this procedure was adopted by Mr. Lister: In removing some cancerous glands from the axilla, a small vein was torn away from the axillary vein at their junction, making, practically, a longitudinal rent in the axillary vein. Taking a fine curved needle and the finest catgut, he stitched up the rent by the glover's suture. The patient recovered without the slightest bad symptom.

Braun (*op. citat.*) relates that Czerny performed this operation upon the internal jugular vein, but hæmorrhage recurred so that acupressure became necessary. Schede was more fortunate. He stitched the femoral vein with a fine needle and the finest of catgut. He then sutured also the sheath of the vessel. Union by first intention followed.

This method of dealing with a lateral slit in a vein has since been followed by many surgeons and has a standard place in surgical technique.

The same considerations are applicable to the lateral suture which have been elaborated in connection with the lateral ligature. When it is performed, the edges of the wound in the vein should be brought out so that, as the thread is drawn up, the internal surfaces of the divided vein-flaps shall be brought in contact. Upon a large vein like the internal jugular, it might be found practicable to hold the wound-edges together by a "through-and-through" continuous stitch, instead of by the ordinary "over-and-over" glover's stitch. This would bring the surfaces of the intima into more certain and extensive contact, and therefore would be preferable. Silk—aseptic—is to be chosen for the suture material on account of the greater ease and certainty with which it may be manipulated. A very fine strand is to be used. The ordinary round sewing needle of the sempstress should be employed for introducing the suture, since the puncture which it makes will be more perfectly filled by the thread that is drawn after it than when a needle with cutting edges is used.

[1] Antiseptic Surgery, 76.

CHAPTER XVIII.

WOUNDS OF BONES.

Peculiarities of Bone as a Tissue—Bone-wounds Complicated with Wound of Soft Tissues—Reparative Processes—The Callus—Consolidation of Fracture and Absorption of Callus—Coaptation and Immobilization of Fractures—Obstacles to Correction—Muscular Spasm—Pain—Interposed Tissue—Care of Skin—Means of Immobilization—The Application of a Plaster Bandage—Permanent Extension—Exposure of Fracture by Incision in Refractory Cases—Direct Fixation of Fragments—Comminuted Fractures—Joint Fractures—Compound Fractures—Susceptibility to Infection—Routine Method of Primary Examination—Recent Injuries with Slight External Wound—Recent Injuries with External Wound of Considerable Extent—The Primary Dressing—Joint Resections—After Treatment—Injuries, Not Recent, and Septic—Energetic Disinfection—Open Treatment—Immobilization—Plastic Splints—Fenestrated and Interrupted Splints—Conditions Justifying Amputation—Bone Grafting.

In considering the wounds of bones, the peculiar structure of this tissue must be borne in mind. Two chief elements enter into the composition of bone: the living, animal cells and mineral salts, the latter constituting about two-thirds of its weight, and being practically foreign or non-living material. It forms a solid framework, within the cavities and channels of which lie the living animal cells. This mineral material, then, is the essentially specialized part of bone tissue, the living cells serving for its deposit, maintenance, and repair.

Although bone-wounds involve a peculiar tissue, whether they are open wounds or simple fractures, they are, in their pathology and treatment, amenable to the same laws which govern wounds in other tissues.

A wound of bone is necessarily associated with the injury and rupture of blood and lymphatic vessels. These injuries not only involve the vessels of the bone, but also those of the periosteum and the sur-

rounding soft tissues. In the case of fracture of the long bones, particularly, this injury to the surrounding tissues is considerable. From the injured vessels there at once begins an exudation of blood, serum, and lymph, and the neighborhood of the injury becomes infiltrated with leucocytes and young cells. The conditions here are precisely comparable to those in a wound of the soft parts (Chapter II.), and so, too, will the healing be influenced by the presence or absence of infection, by the niceness of reposition of the wound-surfaces, by the perfection of immobilization of the wound, and by the nutrition of the parts.

This exudate and newly deposited tissue gradually contracts and results in a spindle-formed sheath about the bone at the site of the fracture. This exudation may extend into the muscular or other surrounding soft tissue. In this is involved the torn or stripped up periosteum. The blood becomes absorbed, and there remains new-formed connective tissue, composed principally of young round cells, and comparable to granulation tissue. This also forms between the bone-ends and extends into the medullary canal of the bone for a short distance from the fracture. This is the beginning of the callus. By the end of the second week, the predominance of round cells has given place to spindle cells, and the new tissue has contracted and presents a very considerable degree of firmness. In places it may be fibro-cartilaginous. Now the callus begins to have a definite outline, and its surface becomes anatomically continuous with the adjacent periosteum. Blood-vessels from the underlying bone have penetrated its substance. During the first few days the process of ossification begins. Large bone cells, osteoblasts, appear, first along the surface of bone. Later they extend out into the substance of the callus. Apace with these cells goes the deposit of earthy salts. This process continues till the callus has become infiltrated with bone salts arranged in the form of cancellous bony tissue, wide spaced and vascular. This process is completed by about the fourth week. The channels and trabeculæ of bone in this new tissue run perpendicular to those of the broken shaft. This same process goes on within the medullary cavity and between the broken bone-ends. Within the medullary cavity the marrow has become replaced by connective tissue, and ossification proceeds from the inner surface of the bone-cylinder toward the centre. This may or may not completely fill

the lumen of the canal. Thus it is observed that the compact portion of the bone is surrounded on all sides by this newly formed spongy bone-tissue. Gradually now the ends of the compact bone become rarefied by the encroachment of osteoclasts—large multinuclear cells which cause the absorption of the earthy salts.

The lacunæ and Haversian canals which have been infiltrated and lined with new cells become enlarged by the melting away of bone material. Thus while the callus is becoming compact the original solid bone is becoming rarefied, and the fracture is found to be solidly united. A gradual disappearance of the primary callus then takes place. It is first absorbed from the medullary canal, and the cavity of the bone becomes re-established. Then an absorbtion from the periphery occurs. As this goes on the deeper or cortical part of the bone becomes more consolidated, and by the time the original contour of the bone is re-established the patency of the medullary canal has been restored and the solid bony shaft is continuous across the site of the wound. All of this consumes many weeks, and often months. The bone is pronounced strong enough to use long before the completion of the healing process.

When the fragments are not restored end-to-end, but are kept together in an over-riding position, the coapted fragments become cemented together laterally, while the prominent bone-ends become rounded off. The cortical layers separating the two medullary canals may become absorbed later and the continuity of the canal be re-established. Loose fragments of bone retain their vitality if not denuded of periosteum. If separated from their vital connections they become absorbed; if infection is present, they die and undergo exfoliation.

The treatment of simple fractures, the same as a wound of the soft tissues, involves particularly the fundamental principles of coaptation and immobilization.

The methods of replacing the fragments into their natural positions must naturally vary much with the location and character of the fracture. In many fractures there is little or no displacement; whereas in others the displacement amounts to a complete separation of a part of the bone to such a degree as to cut it off from vital connection with the rest of the body. Simple fractures of the leg without displacement are often changed into fractures with displacement, or even into compound

fractures, by the patient attempting to use the leg immediately after the accident. It is no uncommon occurrence for simple fractures to be converted into fractures of the compound variety by a sharp point or edge of bone penetrating the skin during the manipulation of the limb or while the patient is being transported. It is, therefore, important that the greatest care be exercised to prevent the injury from being made worse. A fractured limb should be kept as still as possible until the fractured region can be exposed. Trousers legs, drawers, shoes, and stockings should be cut off, if their removal otherwise cannot be accomplished without undue moving of the injured limb.

In the case of a complete fracture of the bones of the leg or thigh, when the limb is moved, it should be supported both above and below the seat of fracture, and grasped in such a way as to prevent rotation as well as angular motion. When the patient is to be moved from the seat of the accident, motion of the fragment may be prevented by extemporized splints of board, straw, rolls of paper, cloth, twigs (Figure 84, *a*, *b*, and *c*, Chapter XII.), or the injured limb may be bandaged to its fellow with a pillow between. The patient should be carried, if possible, in the recumbent position on a litter. The subsequent treatment should be conducted upon a hard bed; that is, a bed with a firm mattress which does not sag with the weight of the body. To accomplish this, a broad, smooth board surface should be placed between the mattress and the springs of the bed.

In the correction of the deformity or the setting of the fracture, the force should be applied gently, firmly, and gradually increasing until the desired result is secured—not quickly and abruptly. When there is simple lateral displacement, the limb should be grasped firmly by the left hand above and by the right hand below the fracture, and, as steadily increasing traction is applied, the lower fragment should be slipped over into place. The same course of applying extension should be pursued in correcting fracture with the over-riding and with rotary displacement. When the muscular resistance to the correction is still greater, an assistant should make counter-extension above and steady the limb while the surgeon, with both hands, applies traction and correcting manipulations. In correcting angular displacement, whether the fracture be complete or of the green-stick variety, extension should

be employed at the same time with the lateral force which overcomes the angulation. The deformity of impacted fracture is overcome by direct extension.

Ordinarily the reduction of fractures is simple and satisfactory; but there are certain obstacles which may intervene. The muscular contraction may be so strong that it resists the combined efforts of surgeon and assistant. A second obstacle to correction is great pain. These two symptoms may be overcome by the use of general anæsthesia. When general anæsthesia is employed, the splint material should be at hand, and the immobilization of the bone should be accomplished while the patient is still under the influence of the anæsthetic. Tenotomy or the subcutaneous division of resisting muscle may be employed to facilitate reduction. Broca and Stimson have been able to relieve spasm by compressing the artery supplying the limb. A third obstacle to reduction is the interposition between the bone fragments of muscle, clot, periosteal tissue, loose fragments of bone or foreign body. When a satisfactory reduction can not be effected because of these things, the seat of fracture should be exposed and the obstacle removed. It should be borne in mind, however, that if no infection is present, none of these obstacles, although they will retard it, will actually prevent the osseous union of the fragments, with the possible exception of a foreign body, for they are all capable of becoming involved in the callus and incorporated in the bone-tissue. One of the great objections to their presence is the fact that they render perfect immobilization more difficult, and thus conduce to non-bony union. This is observed, for example, in the transverse fracture of the patella, in which the interposition of clot and torn periosteum absolutely prevents bony union. A final obstacle to correction is impaction, which may be so firm that it can be overcome only by great force. When this is the case, if the impaction is not broken up, solid bony union is assured; but the surgeon should always have as his guide in the treatment of fractures the idea of the restoration of the parts as nearly as possible to their normal state.

The reduction of fractures should be attempted as soon as possible after the accident. Every hour's delay increases the firmness of the plastic effusion about the seat of the fracture, and renders reduction more difficult. If a fracture with overlapping has been allowed to go

uncorrected, the infiltration with exudate of the surrounding tissues so destroys their elasticity that reduction without operation may be impossible, nor may the surgeon expect to overcome this resistance by general anæsthesia.

Before proceeding further with the treatment, the condition of the skin should be looked to. Excoriations should be covered with mild antiseptic ointment spread upon dry gauze. Serous blebs should be snipped with scissors at their most dependent part, and all of the fluid evacuated. The skin need not be removed, but should be covered with a bland powder, such as zinc oxide, and a few layers of dry gauze. The surface should be examined for prominent points of bone beneath the skin, which might penetrate and render the fracture compound. If such a point is discovered, further manipulation should be resorted to with the view of securing a more perfect reduction. When this can not be accomplished, the danger may be lessened by applying a compressing pad of gauze. Care should be taken that the compression is not made directly upon the threatening point, but over the neighboring bone with which it is connected. No encircling bandage should ever be applied next to the skin beneath a splint unless the rest of the limb beyond is completely covered by bandage equally as firm.

The immobilization of the fragments is accomplished by the following means: by position, by splints, by extension, or by direct fixation. In certain cases, however, the deformity remains corrected without the use of any of these artificial methods. The placing of the parts in a certain position, as, for example, the use of the double inclined plane in fractures of the leg, or the dorsal recumbent position of the body in fractures of the clavicle, often suffices to retain the bones in the desired apposition.

Before the application of a permanent splint, the parts to be covered should be cleansed with soap and water. As a general rule it is well to immobilize both the joint immediately above and below the fracture. The greatest care should be taken to avoid local pressure by the splint apparatus. Pressure should be evenly distributed. Prominent points which may receive undue pressure from the splint should be thickly covered with soft padding. A splint which has been properly applied should give to the patient a feeling of comfort and support to the part.

The persistent continuance of pain means that something is wrong, and the splint should be removed.

Of the materials used for splints the most valuable is plaster-of-Paris, the introduction of which has marked an era in the treatment of fractures. (See Chapter XII., p. 233.)

Before applying the plaster bandage, the skin should be smoothly and evenly covered with cotton wadding or flannel bandage. If the person applying the plaster is skilled in its use, the best covering for a limb is a seamless, white cotton stocking, upon which the plaster may be directly applied. In the case of an ordinary fracture of both bones of the leg, the skin having been cleansed and covered, the patient should be placed upon a narrow table; the assistant, standing on the side opposite the surgeon, grasps the foot firmly in his right hand while the left hand supports the leg at a point just above the seat of fracture. The desired position having been secured, a four-inch-wide plaster bandage is applied about the leg at the seat of fracture, gradually extending above and below as far as the knee and ankle joint. A narrower bandage may then be applied to the foot and ankle, and extending up over the fracture. This should be followed by a wide bandage involving the leg and extending up over the knee. After this the bandages may be continued until the desired thickness has been secured. By applying some long spiral turns or a few longitudinal strips, and by rubbing well together the layers as they are applied, the degree of firmness of the splint may be much increased and the amount of material required diminished. The greatest care should be taken that the pressure made by the dressing is even. The bandage should always be applied perfectly flat, and not with one edge drawn more tightly than the other. The splint may be strengthened by incorporating in it strips of wood-shavings, wooden splints, or strips of wire gauze.

A substitute for plaster-of-Paris is silicate of soda. Bandages impregnated with a solution of this material, after they are once hardened, are not softened by moisture. The disadvantage is that it makes a less firm dressing than the plaster. When it is desired to render a plaster splint impervious to water, it may be coated over with a solution of silicate of soda or with varnish.

Instead of the plaster bandage may be used in some cases moulded

splints made of soft materials which harden after having been pressed against the part and made to conform to the desired shape. (Chapter XII., p. 230.)

For many fractures, as of the femur and the bones of the forearm, non-pliable splints made of wood or metals are preferable.

When the tendency to over-riding of the fragments is persistent, the application of permanent extension becomes necessary. This is ac-

FIG. 107.—Fracture of tibia immobilized by clamp and screw apparatus (*Parkhill*).

FIG. 108.—Clamp ready for removal at first dressing, end of six weeks.

complished by attaching a weight to the extremity, or by elastic extension, or by using the weight of the limb itself to overcome the deformity.

In certain cases, despite the best efforts, the fragments can not be made to remain in satisfactory apposition. When all other resources have failed, the well-equipped surgeon is justified in exposing the seat of fracture, and applying such local treatment as the conditions require.

The incision of operation often liberates an amount of blood and serum, the presence of which has been an obstacle to reduction. The removal of soft tissues, which have fallen between the bone-ends, can then be accomplished. Often nothing further is required. But when the surgeon feels that neither splints nor extension will suffice to hold the fragments in place, he should proceed to the direct fixation of the bone-ends. Direct suturing or binding of the bone-ends by means of wire, silkworm-gut, or chromicized gut, is often indicated. Nails and pegs of bone, ivory, or metal may be used; or organic or metallic plates, or organic ferrules or cylinders, or external metal plates controlling the deeper bone fragments by long screws, as in Figures 107 and 108.

In the case of simple wire sutures, the ends may be left long enough to project through the wound, which is closed throughout, and covered by copious dressings. With the ends as a guide, the wire may be cut and easily removed after it has served its purpose.

In dealing with comminuted fractures with irreducible displacement, after extension, manipulation, anæsthesia and tenotomy have failed, the same general principles, stated above, apply. Here the surgeon often has to do with loose fragments of bone which have become entirely separated, and often so displaced as to form the chief impediment to reduction. Such fragments should usually be removed. If replaced and allowed to remain, their tendency is to become exfoliated, though this tendency is being overcome by the perfection of surgical technique. After the removal of a large fragment of bone from the leg or forearm, the parallel bone prevents the bone-ends coming together. In such case an equal amount may be resected from the sound bone, if the amount of bone required to be removed is not so great as to destroy the usefulness of the muscles. When the gap is too great to be thus treated, it may be filled with bone from a foreign source, or treated by an osteoplastic lengthening of the injured bone.

The involvement of a joint by a fracture adds another element of importance. As a result of the injury to the joint, there is an intra-articular effusion of blood and serum, and the traumatic reaction about the line of fracture causes the formation of plastic exudate upon the synovial surface. For this reason ankylosis, due to the adhesions of the new-formed plastic exudate to the opposing synovial surface, is prone

to develop when the joint is kept immobilized for any considerable time. Moreover, motion of the joint immediately after the injury increases the amount of exudate and effusion, and thus increases the liability to ankylosis. The guiding principle, therefore, in the treatment of such fractures, is immediate and complete immobilization, and, later, carefully applied passive motion as soon as the traumatic reaction has subsided, and as soon as is consistent with the measures applied for the immobilization of the bone-fragments. The early application of the ice-bag will diminish the effusion of fluid into the joint. Evenly applied pressure by means of a flannel bandage has the same effect, but is less desirable during the first few days. Later, at the end of two or three weeks, when the acute reaction has subsided, massage, heat, and pressure will hasten the removal of the effused fluid. If the amount of fluid is very great, or if these methods fail to cause its absorption, the joint must be aspirated, or incised, and cleaned out, if the distension is due to blood-clot. When immobilizing such a joint the surgeon should always have in mind the possibility of the danger of ankylosis; and when consistent with the treatment of the fracture itself, he should endeavor to place the joint in such position as shall render the limb the most useful should this untoward result occur. Ankylosis should later be overcome by carefully applied passive motion.

The treatment of compound fractures is based upon the same principles as govern the treatment of wounds of soft parts plus the principles which have already been laid down for the treatment of fractures.

The conditions presented by those lacerated and contused wounds, which are complicated by fractures of bones communicating with the wound, are such as are very favorable to the development of septic disturbances in their most aggravated form. Phlegmonous inflammation, prolonged suppuration, more or less sloughing of the contused and lacerated tissues, and necrosis of bone, are the ordinary attendants of the healing of such wounds when adequate precautions against sepsis are not observed in their treatment; while in this class of injuries, more than in any other, have the more formidable septic complications of erysipelas, gangrene, septicæmia, and pyæmia been rife.

The special feature possessed by these wounds which tends to aggravate the difficulties attending the treatment of severe lacerated and con-

tused wounds in general is the irritation of the wound by the movements of the bone fragments within it. The law of rest is thereby continually being violated, and a favorable condition for the development of septic disturbances maintained.

The treatment of these cases should be conducted from the first in such a way as to prevent, if possible, septic contamination, or to destroy or control it, when efforts at primary prevention have not been made, or have failed.

The difficulties which will attend the treatment of these cases will depend on the extent and character of the traumatism which has been inflicted, and upon the time at which they came under the care of the surgeon.

For purposes of convenient consideration they may be classified into three groups: 1. Cases in which the injury is recent, and in which the external wound is a slight puncture only of the skin. 2. Cases in which the injury is recent, and in which the external wound is of considerable extent. 3. Cases which are not recent, and which have already become septic. In all cases of compound fracture a certain routine method of primary examination should be followed, the later manipulation being guided by the revelations of this examination. A superficial irrigation of the wound with a sublimate solution, 1:2000, should first be made, and over the wound should then be placed a copious gauze dressing wet with the same solution, and a temporary immobilizing splint should be applied at the place where the injury is received. After the patient has been removed to the place for permanent dressing—preferably the operating room of a hospital—he should be placed upon a table, and the region widely about the wound should be exposed. In the more severe cases requiring considerable manipulation, it is best to administer a general anæsthetic before the temporary splint is removed. If the fracture is one of the leg, it should be rested upon a sand-bag, which can be made to conform in shape to the posterior contour of the limb. The surrounding field should be covered with towels wrung out of the sublimate solution. A bit of gauze should be held against the wound while the whole leg is thoroughly scrubbed with soap and water, shaved, and, especially the region just about the wound, cleansed with ether and the sublimate solution. The wound should then again be thoroughly irrigated

with the sublimate solution, and its extent and the character of the fracture discovered by exploration with the surgeon's finger, all manipulations being conducted in strict accordance with the tenets of aseptic work as described in Chapter VI. The use of antiseptic irrigations as a routine in compound fractures is based upon the assumption that the surgeon has to do with a wound which, unlike an operative wound, is one inflicted through an infected region, and by such irrigation the surgeon may hope not only to remove gross foreign material, but also to remove or destroy the infective organisms present in it.

If the injury to the soft parts is but slight, the displacement of bone inconsiderable, and the amount of hæmorrhage and effusion small, the wound should be partly sutured, leaving always a small opening for drainage. Into this may be introduced a slender strip of gauze drain, and the whole covered with moist antiseptic gauze. Often the wound is the merest puncture of the skin, with no other conditions to distinguish the fracture from the simple sort. In such a case, after thorough cleansing, it is only necessary to cover the wound with the usual dressing. In no case is it recommended to hermetically seal the wound of a compound fracture.

RECENT INJURIES WITH EXTERNAL WOUND OF CONSIDERABLE EXTENT.

Should the examination show that there is considerable injury to the soft tissues or irreducible displacement or the presence of foreign matter, the surgeon should have no hesitancy in freely enlarging the wound or making such new wounds as shall give the best access to the seat of injury. There should be no timidity in multiplying the number of longitudinal wounds, for in these cases abundant provision for drainage is most desirable. All coagula and foreign matter are removed and the wound cavity is thoroughly irrigated with the sublimate solution. It often becomes necessary to repair ruptured muscles, tendons, nerves, or blood-vessels. Loose fragments of bone should be removed, and the bone dealt with if necessary by some of the methods of direct fixation already described. In closing the wounds, the provisions for drainage should be abundant. It is well in the more severe cases to apply a large

dressing, and immobilize the bone by a temporary splint. At the end of four or six days—or sooner or later, varying with the degree of the patient's temperature, the amount of hæmorrhage, or of serous discharge—this splint should be removed and the wound dressed. Drainage tubes should be irrigated through and through to insure their patency, and gauze drains should be renewed or removed. From this time on, the surgeon should be guided in the dispensing with drainage, in the shortening of drains, in the instituting of new drainage, in the application of secondary sutures, and in the general management of the wound, by the general principles for the treatment of wounds.

The treatment now detailed is to be employed not only when the wound communicates with a fracture of the shaft of a bone, but also when a joint cavity is opened into by the wound.

If the joint is not opened by a direct penetrating wound, but only by a fissure through the articular extremities of the bones forming the joint—an occurrence which may be verified by the hæmorrhage into the joint—the joint cavity should be opened by a free incision at a suitable point, and should be emptied of all serum and coagula, disinfected and drained. In given cases, the procedure amounts to nothing more nor less than a partial and irregular resection of the joint, the features of which will suggest themselves in the special conditions which these wounds will present in which antiseptic conservative methods will hereafter be more frequently adopted. Total resection will be limited, henceforth, to very grave cases.

The after-treatment is very simple, provided thorough asepsis has been obtained. In favorable cases, where healing by first intention is secured, a single change of dressing, after six to eight days, for the removal of sutures and drainage-tubes, is all that is necessary. The second dressing remains to the time of complete healing. In ordinary cases, where the wound does not show a tendency to primary union, the dressing is changed every two to four days, according to the amount of discharge. The manipulations should be restricted to simply cleaning the surrounding integument with a pledget of absorbent cotton moistened with an antiseptic lotion, being careful not to disturb its relations. The drains should be removed as soon as the secretions cease to flow through them. The dressings should be renewed till the wound is

filled with granulations up to the level of the surrounding skin. It will then suffice to apply a more simple protective dressing, covered by a plastic splint, as in subcutaneous fractures, till consolidation has taken place.

At as early a stage as possible a permanent splint should be applied, with suitable provision for dressing the wound without removing the splint. A small, dry dressing, quadrilateral in shape, having been applied, and the dressing covered with the impervious oiled-muslin of the shops, a plaster bandage should be put on over all. Before the plaster has become thoroughly hardened, a fenestrum, outlining the dressing, should be cut. The oiled-muslin should then be cut through and reflected back over the four edges of the fenestrum in such a way as to prevent the moisture of the dressings softening the plaster. The outside of the case may be painted with varnish or water-glass to render it impervious to moisture. If more than one fenestrum is required, or if the fenestrum must involve more than half of the circumference of the case, the splint should be strengthened by incorporating into it a strip of basswood or a metallic splint. The same end can be accomplished by introducing an iron splint which passes down as far as the fenestrum and then leaves the case and curves over the opening to re-enter the case below. (See Figures 109 and 111.)

INJURIES, NOT RECENT, AND SEPTIC.

As injuries which are "not recent" are to be comprehended those which come under treatment after the lapse of twenty-four hours. The task to establish an aseptic course in these cases is obviously much more difficult; each patient, however, will present its special conditions, so that we have here, also, to differentiate between favorable and unfavorable cases, each kind requiring different treatment.

The more favorable cases are those which do not show an extended wound-reaction, even though unmistakable signs of infection of the wound are present. According to past experience, there may yet be secured in such cases progressive healing by granulation, though frequently with long continued suppuration, and often with necrosis of the ends

of the fractured bone. The method to be pursued in these cases is virtually the same as in infected wounds of the soft tissues—namely, enlargement, exploration, and disinfection of the wound, with free drainage and protective dressings with immobilization.

Contrasted with these favorable cases are to be placed those in which the pronounced picture of local sepsis is presented, either in consequence of neglect of antiseptic treatment, or of the inefficiency of that which has been employed. In these cases will be observed all the signs of active sepsis, an abundant offensive purulent discharge, marked inflammatory reaction in the surroundings of the wound, in some cases gangrene of the badly contused soft parts, and progressive infiltration of the connective tissue with pus and gas.

Energetic disinfection is again demanded in these cases, though undeniably attended with greater difficulty, and not in all cases possible to be absolutely attained. All infected tissues must be freely laid open by incisions, so as to give entrance to the disinfecting substance and exit to the ptomaine-laden secretions; all gangrenous tissues must be removed with knife and scissors. Long incisions and counter-incisions should be made to open up the torn and infiltrated interstices of the muscular tissue. Where there is extensive subcutaneous infiltration of blood, as well as in those cases in which there is already present phlegmonous infiltration, numerous small incisions should be made, in addition, through the integument, for the removal of blood, pus, and gases, and to enable the disinfecting fluid to be introduced in as many places as possible. These multiple scarifications will render important service in opening the spaces between the long incisions. They should all be subjected to thorough antiseptic irrigation, and be kept open by small drainage-tubes.

Neither occlusion nor compression of the wound can be adopted in such cases, while it is further important that the changes which may be going on in it be capable of being observed at any time. For these reasons an open treatment, with permanent antiseptic irrigation, is required (Chapter XIII.).

This treatment should be continued until all evidences of active infection have been overcome, and healthy granulations have been secured; the after-treatment is then conducted as for any healthy open wound.

IMMOBILIZATION OF THE INJURED PARTS.

Means of immobilization must be resorted to both for the protection of the injured soft parts, and for the retention of the bone-fragments in proper position until consolidation has been accomplished. The presence of an open wound introduces elements of greater difficulty into the problem of immobilization than when a simple fracture is being dealt with, for, either the fracture-dressing must be removed every time the wound is examined, and then renewed, or must be so constructed as to leave exposed the wound and its surroundings. The latter plan is to be preferred, but is attended by greater technical difficulties, which grow with the circumference of the wound, and may be insurmountable in very extensive or multiple wounds.

Except in the more simple and favorable cases the use of a permanent plaster-of-Paris dressing, applied so as to encircle the limb, and fenestrated, is not compatible with the requirements of the dressing of the wound during the earlier days of its course. After the first critical period has passed, however, and the wound has become covered with granulations, and the amount of its secretions have somewhat diminished, such a dressing will be applicable. In cases of fractures occurring in patients suffering from delirium tremens, this dressing is indispensable.

During the first period of the treatment of these injuries, only such a means of immobilization should be employed as will allow the wound to be enwrapped with a protective dressing that will extend over a wide circumference about it. Not always the same kind of dressing will answer; the seat of the fracture and the special conditions of each case should be our guide.

Plastic splints are to be recommended in most cases. Those made of cloth saturated with plaster-of-Paris and molded to the part are especially applicable, as they can be adapted to any part of the body. The width of the splint should extend over about two-thirds of the circumference of the limb. In general, the splint is applied over the absorbent dressing, if possible, on that side of the limb where it will be least soiled by the wound secretions. They should be secured by moist starched bandages, so that the turns, when dry, will firmly adhere to each other.

For suspending the limb, holes may be punched in the splint, and cords for suspension drawn through them.

Such splints can easily be removed at each change of the dressing.

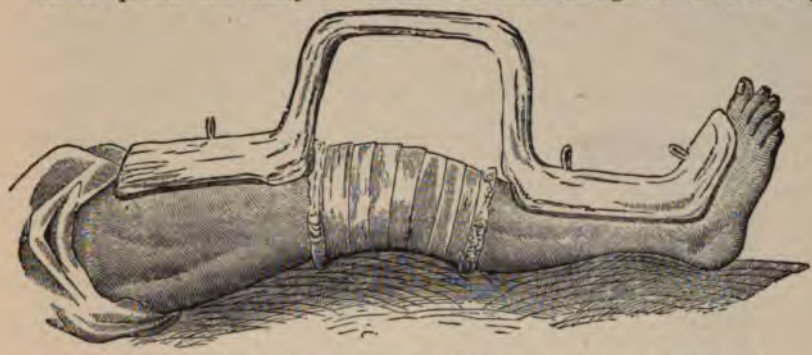

FIG. 109.—Bowed plaster splint for compound fracture of the knee-joint (*Beely*).

In some cases, however, in which the wound is not too large, and is favorably located, the splint might be enclosed within the antiseptic dressing, so that it might remain when the latter is changed. In such a case,

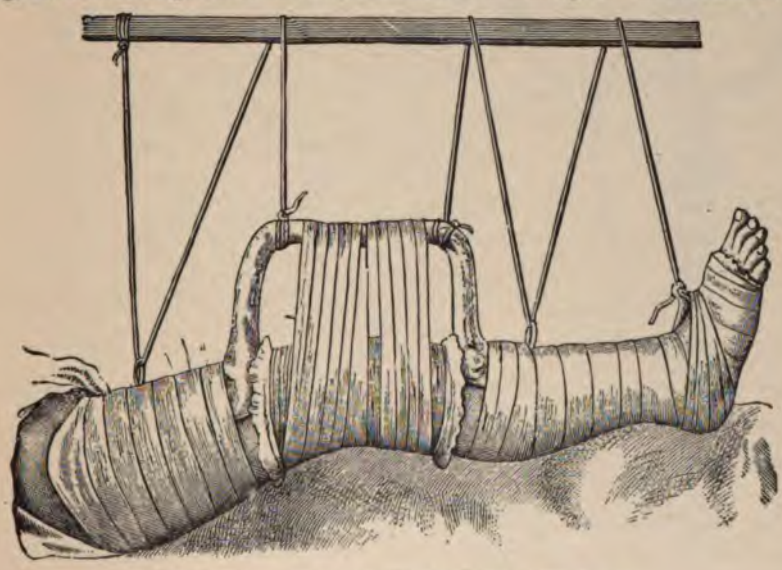

FIG. 110.—Bowed plaster splint, applied and suspended.

the splint should be narrowed opposite the wound, and wrapped in impermeable tissue or lined with antiseptic cotton. It may then be placed directly upon that part of the limb opposite the wound, next to the skin.

Over all, the antiseptic dressings are to be applied, and the whole secured as before recommended.

Another way to avoid removal of the splint, when the wound-dressing is changed, is to have a ∩-shaped arch formed on the splint, opposite the wound (Figure 109), so as to render the wound and its surroundings accessible all around. Such a splint would need to be reinforced by a strip of hoop-iron, bent in the same way, and inclosed in the plaster. Such a splint resembles much the interrupted circular splint (Figure 111).

FIG. 111.—Interrupted plaster dressing (*Esmarch*).

Concave splints of wood, tin, or wire, applied over the wound-dressing, may be used to advantage in many cases.

Some kind of suspension-splint, with extension by means of adhesive plaster strips, a weight and pulley, affords, as a rule, the best advantages for carrying out the antiseptic treatment of a wound complicated with fracture.

The fenestrated or interrupted plaster-of-Paris encircling splint may be employed with advantage as soon as the process of healing has sufficiently advanced to exclude danger from sepsis and inflammation. This period may arrive within two or three weeks, if the conditions are favorable, but may be delayed for a much longer time. When the secretions have nearly ceased, the wound is covered with granulations, and the incisions have either healed or have become superficial granulating surfaces, the perfect immobilization of the fracture assumes greater importance than the rigid antiseptic treatment of the external wound. No method of fracture-dressing can secure the desired immobility of the bone-fragments, and yet permit the necessary attentions to the wound, so well as the encircling plaster splint, fenestrated or interrupted.

The interrupted plaster dressing (Chapter XII., p. 234) is suitable in extensive injuries of the soft parts, or in multiple incisions and counter-incisions. The bridges (Figure 111), preferably of sheet-iron, which connect the two pieces of the dressing should extend along the whole length of the sections of the dressing into which they are inserted, and should be applied, one externally and the other internally, to the limb. They should be fastened by a sufficient number of turns of plaster bandage to give the apparatus sufficient strength. The margins of the dressing in the neighborhood of the wound should be carefully chinked with such an antiseptic material as borated gauze or cotton.

As soon as the external wound is cicatrized, the fenestrated or interrupted splint should be replaced by an ordinary plaster dressing to be worn until firm union of the bone is accomplished.

CONDITIONS JUSTIFYING AMPUTATION.

Three conditions arising in compound fractures justify immediate amputation: injury to the blood-vessels so great as to cause the death of the part, uncontrollable suppuration, and wide loss of bone-substance. It is often evident at the first examination that the injury to the vessels has been so great that the parts below the wound must become gangrenous. In such cases the extremity is found to be cold and to present a gradually increasing livid color. The main vessels may be found to be divided or thrombosed. Pressure upon the skin or nails does not show the return of blood into the capillaries of the area from which it was expressed. In such cases amputation should be done. On the other hand, examination may show the extremity to be cold and the main vessel pulseless; but if all of the signs of death of the part are not present, the surgeon should endeavor to save the limb, inflicting, as he proceeds with the examination and dressing, the least possible traumatism, and finally applying the bandages as loosely as possible. In all cases an effort should be made to preserve the extremity unless it is unquestionably beyond saving. Nor even then is immediate amputation always called for. If the patient is suffering from shock, extreme depression, or anæmia, or if other conditions are present which render the continuation of operative procedure extra-hazardous, the parts should be thor-

oughly cleansed, hæmostasis secured, a large, moist antiseptic dressing applied, and further operation deferred. If circular compression is used to control the hæmorrhage previous to amputation, it should be applied as low down as possible, preferably directly over the wound, as the vitality of the tissues below the pressure is greatly impaired, and flaps involving such tissue may be expected to slough.

When in a compound fracture, notwithstanding free and wide incisions, abundant drainage and irrigation, because of some constitutional or local condition, uncontrollable suppuration persists and septicæmia threatens the life of the patient, amputation well above the suppurating area should be done. The same operation is necessary when, because of local disturbance to the blood-supply, infection is causing a gangrene of the extremity. Amputation is also indicated in cases in which there is so much bony destruction that, in order to bring the bone-ends together, the limb must be shortened to such a degree and the soft tissues so folded as to render the limb less useful than an artificial substitute, or to give rise to gangrene because of obstruction to the circulation through angulation of the vessels. In cases such as this, an effort may yet be made to save the limb by means of an osteoplastic operation or by the transplantation of bone to fill the defect.

Although every effort should be made in the line of conservative surgery, still there is a fourth class of cases in which amputation is indicated: these are the cases in which, in order to preserve the limb, a very long and trying period of treatment must elapse, with continuous suppuration and confinement; all of which must have a depressing effect upon the health of the patient, must threaten the integrity of vital organs, and end in securing only an imperfect limb. The age, sex, and occupation of the patient, the location of the injury and the adaptability of prothetic apparatus to the particular part should be taken into consideration; and finally, with a full understanding of the case, the patient himself may be called upon to elect the course which he would have pursued.

BONE-GRAFTING OR TRANSPLANTATION.

In the conservative surgery of bones much interest and importance is attached to the grafting or transplanting of bone-tissue. When a de-

tached piece of bone is transplanted, or when such a piece is replaced after having been separated from its vital connections, as the replacing of a button removed by the trephine, one of two courses may be followed by the implanted fragment. If suppuration takes place the fragment perishes and acts as a foreign body, the suppuration continuing until the foreign material has become removed. Thus, if the fragment has been replaced with the hope of its growing fast, the first sign of suppuration informs the surgeon that the permanence of the implantation is out of the question, and the sooner it is removed the sooner the suppuration will be controlled. On the other hand, if the operation has been accomplished without infection, the implanted bone will remain unirritating and permanent so long as free from infective organisms. If it is immobilized, in intimate contact with the surrounding bone, after the lapse of sufficient time the gap which it fills will be found to contain living bone which has united with the bone which surrounds it. It was formerly supposed that the implanted fragment became grafted upon the other bone, and that it continued to live just as does a piece of transplanted skin. This, in the light of our present knowledge, is known not to be the case. What happens is this: The implanted bone loses its vitality and becomes in every sense of the word a foreign body, just as much as though it were a piece of sterilized sponge or wood. It becomes surrounded by young connective tissue or callus springing from the surrounding living bone. Its cells perish and become so much albumen. The highly vitalized new cells from the embedding callus penetrate its spaces and channels once occupied by living cells, and replace the degenerated occupants of these spaces. From the surrounding living bone goes the process of ossification, osteoblasts invade the new tissue, and the callus becomes ossified. This ossifying process finally reaches the transplanted bone, the spaces of which have become filled with the new granulation tissue. Osteoclasts consume its mineral matter, and new bone is formed within its very chambers. This process goes on until the old bone has disappeared and entirely new bone has taken its place. Thus it is seen that it has served the purpose simply as a scaffolding upon which a new structure is built, and with the completion of which the scaffolding is removed.

Up to the present time attempts at the transplanting or reim-

CHAPTER XIX.

WOUNDS OF THE HEAD.

Anatomical Considerations—Superficial Wounds of Scalp—Bruises and Contusions—Punctured and Incised Wounds—Extensive Lacerations—Superficial Gunshot Wounds—*Deep Wounds of Scalp with Injuries to the Cranium*—Signs of Compression of Brain Absent—Fractures of the Skull—Indications for Trephining—Fractures of the Base of the Skull—*Intracranial Hæmorrhage*—Brain Compression—*Opening the Skull*—The Trephine—Enlarging Openings in the Calvarium—*Wounds of Intracranial Vessels and Sinuses*—Ligation of Cerebral Sinuses—Wounds of Middle Meningeal Artery—*Injuries to Cranial Nerves—Wounds of Brain-substance*—Hernia Cerebri—*Wounds during Birth—Bandages for the Head—Wounds of the Face*—Wounds of the Eye—Wounds of the Ear—Wounds of the Mouth.

ANATOMICAL CONSIDERATIONS.

THERE are many points in the anatomy of the skull which are of paramount importance in considering the nature and occurrence of wounds of its component bony parts and of injuries to the substance of the brain; but those especially concerning us when considering the treatment of these lesions are comparatively few, and can be covered in a few words. The periosteum of the cranium—usually called the pericranium—is thin but quite strong and resistant. Except over the sutures and at the great foramina it can be easily stripped off, or even made to glide over the bone. In old people its connection with the bone is more firm. It is nourished principally by vessels from the bone. Concerning the bones themselves it should be remembered that the diploë is wanting in the young and in those in advanced life.

Of great importance are the connections which the veins of the superficial soft parts enjoy with the sinuses of the cranial cavity and the veins of the diploë through the emissoria Santorini. The most important of these anastomoses are: 1. Among the occipital veins, which connect through the mastoid foramen with the lateral sinus. 2. Along and around the inter-parietal suture, especially its posterior extremity, where

numerous openings connect with the superior longitudinal sinus. 3. The ophthalmic veins, according to Sesemann's investigations, empty as well into the cavernous sinus as into the facial veins. By this it will be seen that the sinuses of the brain have their overflow outlets, or "waste weirs," in what would seem to be abundance. On the other hand, this freedom of venous connection increases the danger from pyæmic or thrombotic trouble in cases of infection or phlegmon of the external soft parts.

SUPERFICIAL WOUNDS OF THE SCALP.

It will be well at the very outset of our consideration of this subject to give the greatest possible prominence to the classical dictum, "No injury of the head is too slight to be despised, and few too severe to be despaired of;" a statement only strengthened by time and experience. The temptation is very great to ignore trivial wounds, to insufficiently cleanse them, to carelessly dress them. If nothing else teaches the danger of carelessness in these cases the experience gathered from the sword duels of German students should be convincing, since deaths often are caused by apparently trivial or commonplace wounds.

We may divide injuries to the scalp and adjoining soft parts into bruises and contusions, penetrating or incised wounds, and extensive lacerations, and discuss their treatment accordingly.

Bruises and Contusions.—A mild bruise or contusion, without abrasion of the scalp or harm to the bone, may be dressed with ordinary evaporating lotions, or cold applications either in ice-bags, or by compresses frequently wet in cold water. If there be any superficial abrasion the hair should be disentangled from the wound and cleansed of clotted blood and secretions and some mild antiseptic applied. Any ordinary effusion of blood between scalp and bone will be checked and then rapidly reabsorbed under this treatment and the application of gentle pressure. The hair may be cut short, or shaved if occasion require. If effusion be very great, and apparently not checked by simpler measures, then it may be well, after shaving and cleansing an area of the scalp, by free incision to turn out the more or less fluid blood, search for bleeding vessels, twist or tie them with catgut, wait until bleeding has stopped, and then suture the wound or introduce a tampon of gauze impregnated

with antiseptic powder, which answers the purposes of drainage and pressure.

Rest and avoidance of exposure must then be enjoined.

Punctured or Incised Wounds.—A small punctured wound, as made by some sharp instrument, should be treated by shaving the hair about the wound, careful cleansing, and then by applying a moist antiseptic dressing. A small knife-blade, the point of a foil, or other pointed instrument may pierce the soft parts over the course of some vessel, and without doing material injury to the bone sever or wound an artery or vein. Several cases of aneurism of terminal vessels have been reported as occurring in this way. From such a wound hæmorrhage would be free, while it would be easy to recognize whether an artery or vein, or both, had been injured. If a vein, pressure will in most cases be sufficient; this pressure should be made a part of the antiseptic occlusion, being maintained by the firmly applied bandage which holds the dressing in place.

But if an artery be wounded and such pressure be insufficient, the next measure should be the introduction of a needle threaded with silk or catgut, which should be passed, close to the wound, under the vessel and then out; the thread can then be tied in a simple knot or over a compress tight enough to constrict the same. A hare-lip pin or even a common pin may be used instead, a thread being tightly twisted over it in a figure-of-eight. If this measure be required it should be done on either side the cut, which should be then cleaned and occluded as before. Or, if required, the wound may be freely extended with a scalpel, the hair having been removed, and then the bleeding vessel caught and secured. After this, careful cleansing, approximation and occlusion as before. Punctured and incised wounds in those parts of the scalp not covered by hair should be sutured in order to secure the best cosmetic results. Indeed, it may be laid down as a general rule that wounds of the forehead in which there is any tendency to gaping should be closed by suture. The method of approximating the edges of such wounds by means of sticking-plaster is not to be considered. Properly applied sutures of fine silk greatly facilitate the healing of such wounds, by bringing the wound-surfaces in apposition, by checking hæmorrhage, and by acting as a splint to immobilize the tissues during the process of healing. The su-

ture line should be dusted with some non-irritating antiseptic powder, such as nosophen or bismuth sub-iodide, and covered with a gauze dressing. If the wound is dry and clean it is not necessary to apply any gauze at all. The further consideration of the suturing and dressing of wounds of the scalp is continued below.

Extensive Lacerations.—Extensive lacerated or complicated incised wounds are often inflicted which may even strip the pericranium off the bone, yet without causing any more dangerous symptoms than a temporary concussion. In these cases, after having satisfied himself that no fracture of the bone has occurred, at least none calling for operative procedure, the surgeon should first attend to the more prominent bleeding points, and shave the hair about the region of the wound. He should then, with sponge and forceps, address himself to the removal from the wound of every particle of dirt and every loose hair. Often this cleansing may be done better by free irrigation and brushing out the wound with gauze or a brush. Any shred of tissue about whose vitality there is the least doubt had better be clipped off. The principal bleeding being checked, it remains now to close the wound. The scalp is so richly supplied with blood-vessels that there is an active oozing from the whole surface of the wound. It is unnecessary to attempt to check all of this bleeding before closing the wound, because it stops when the sutures are tied. One cannot be too careful to convince himself that every speck of dust has been removed. If now the pericranium has been stripped up, its edges may be approximated with fine catgut. Or if its edges closely correspond with those of the scalp, they may all be included in one stitching. It often is well to omit a stitch at each angle or end of the wounds to allow for the escape of secretions, should any form; though if all these precautions have been observed one may expect union *per primam intentionem.*

Rather fine silk is perhaps the best material for these sutures. Stitches should be placed about a quarter-inch apart, and may be either continuous or interrupted, according to the fancy of the surgeon; excellent results may be achieved with either. The subcuticular suture may often be used to advantage in wounds of the forehead. If drainage seem to be indicated, it may be accomplished by a fold of gauze laid especially in those angles of the wound which are to be dependent. The

tying of the natural hairs of the part for the purpose of approximating the lips of an incised wound of the scalp is to be deprecated when proper suture materials can be secured.

The wound being neatly closed, it may be freely covered with some non-irritating powder, as mentioned above, to prevent the dressing from sticking, and dressed with dry or moist sterilized gauze held firmly in place by a moistened bleached muslin bandage. The powder may be omitted and a moist antiseptic gauze compress placed directly upon the wound.

This dressing need not be changed for from two to six days, depending upon the presence or absence of infection. Infection beneath the scalp often causes a rapid accumulation of pus. Within two or three days the scalp may be lifted up for a considerable distance. When this accident occurs the wound should be opened at a dependent part, the pus evacuated, and the wound freely injected with peroxide of hydrogen or thoroughly washed out with sterile water.

In those cases which occasionally occur where some part, or nearly the whole, of the scalp has been torn off, or loosened, as by machinery or "scalping," if the patient be seen in time, an effort should be made to replace the loose portion. Some astonishing successes in these cases have been reported, and at least no harm is done if the trial fail. The general rules already given are sufficient to guide the reparative effort; accurate approximation and judicious pressure being the important canons of treatment along with careful asepsis. Should the effort partially succeed or fail, if the loss of substance be small, a plastic operation may be attempted; otherwise the bare or raw surface must be kept clean, healthy granulations stimulated by some such application as naphthalin or amorphous boracic acid, and, when attained, the healing process still further assisted by skin grafting or other plastic operation. No case of this kind which is not speedily and primarily fatal need be despaired of.

It should always be borne in mind that suppurative processes about the cranium may, by the transmigration of micro-organisms, give rise to infections of the meninges or the brain, resulting in acute meningitis or cerebral abscess; and for this reason great care should be exercised in preventing such infection, in freely liberating retained pus, and particularly in the presence of exposed or injured cranial bones.

It may happen that we have a case to deal with which has already become infected. We should then proceed as follows: The region of the wound should be carefully shaved. If the appearance of the part, or the general condition of the patient, indicate any septic process, the wound should be opened, and its interior freely exposed to view, while a most painstaking disinfection of its entire surface should be made. Suppurating or foul spots or surfaces should be thoroughly cleansed, new openings made for drainage in most dependent parts, and, according to circumstances, the edges reunited, the whole left more or less open and drained, or putrefying and necrosed tissue removed with knife, scissors, or curette. Abscesses should be freely laid open, and their cavities scraped out if necessary. If a diffuse cellulitis have supervened, the scalp should be covered with large compresses saturated with a solution of bichloride of mercury or acetate of aluminum. Erysipelas of the scalp should be treated according to the rules laid down elsewhere for the treatment of that disease. When we bear in mind the anatomical connection of the scalp and deeper parts (*vide* first paragraph of this chapter), it will be understood that all attacks of erysipelas about the scalp are at least serious.

When called to treat the later results of former injuries in the line of granulating or sluggish ulcers, or exposed and carious or necrotic bone, there are no indications in their case calling for different treatment than similar conditions elsewhere on the body. A healthy ulcer may be covered by skin grafts, or by a plastic operation; an unhealthy one should be first rendered healthy, and this best, perhaps, by aid of naphthalin and boracic acid and an occasional stimulating with caustic. All dead or dying bone should be removed with curette or chisel, and the surface then allowed to heal by granulation, or covered by a plastic operation, or both.

Superficial Gunshot Wounds should be treated on the general principles above enunciated; but it must be remembered that a bullet may not only pursue a devious and tortuous path, but may carry in foreign matter. Such a wound should either receive primary antiseptic occlusion, or its track be carefully cleansed and drained, being laid open for this purpose if necessary. After thorough disinfection it does not differ from any other wound of the scalp, so far as indications are con-

cerned. Bullets may be left until a subsequent convenient time for their extraction, or they may be searched out at once and removed.

DEEP WOUNDS OF THE SCALP, WITH INJURIES TO THE CRANIUM.

Those in which there are no Signs of Compression.—The first procedures in these cases are not different from those already mentioned. An antiseptic cleansing of external surfaces, and a removal of hair in the neighborhood of the lesion, are first to be effected. Next should follow a checking of the hæmorrhage, as before described. Then a careful examination of the wound should be made. Should it appear that a small external wound conceals more extensive injury or laceration beneath, then free incision should be made in order to expose every part to sight or touch. According to the extent of these deeper lesions should the superficial wound, as now extended, be reunited or not.

It may happen that one or more pieces of the external table may be entirely separated from their bony surroundings, and held only by their connections with the periosteum and soft parts. Not forgetting that they may be still nourished by these connections, it is, on the whole, the safest plan to remove them. But should a prominent process of bone be thus detached from its seat—as, for instance, a part of the supra-orbital ridge, or margin of the orbit, or even the mastoid process—it would only be good practice to make every endeavor to save it. Such a fragment may be held in place possibly by pressure, by stitching together edges of periosteum, or by drilling and inserting catgut sutures. But pieces of bone that lie entirely loose should be unhesitatingly removed, even if the dura mater or brain be thereby exposed.

Should hæmorrhage from a denuded external surface of bone or oozing from the deeper portion occur and delay the surgeon, it may be checked by compression for a few moments with iodoform gauze, by crushing in the diploë, or by applying sterilized wax. After it has been once fully checked it is not likely to recur after the parts are closed in from the air, as when the dressing with suitable compression has been made.

Aside from leaden projectiles a variety of foreign bodies may not only injure the cranial bones, but parts of them may even be embedded;

workmen's pointed tools, knife-blades, bayonets, sword or foil points, arrow-heads, hatchet or tomahawk points, pieces of glass, etc. In proportion as these penetrate deeper, the gravity of the wound and the possibility of depression or perforation of the inner table are greater; but the indications do not differ greatly so far as the therapeutic measures are concerned. Obviously their removal is called for, in most cases at least, and this should be accomplished with the least possible disturbance. If a simple pull be insufficient, enlargement of the external wound and instrumental aid must be resorted to. Strong forceps, a pointed elevatorium, a removal of surrounding bone by means of chisel or gouge, and possibly even the trephine, may be called for. The more recent the case the better, as a rule, the results. If any pointed instrument should evidently have penetrated the cranium, it should be removed by the most direct pull in the direction of the line of its entrance, so that farther injury to brain tissue or coverings may be avoided. As more or less hæmorrhage may take place from the wound in the tables of the skull immediately after removal of the body, especially if it have penetrated, a bit of gauze should be plugged into the wound, or the head at least placed in such a position that bleeding into the cavity of the cranium may not take place.

In every case where solution of continuity of the outer table has occurred, the surgeon should bear in mind what a vantage-ground the diploë offers for the lodgment of septic germs and for the development of inflammatory and septic thrombotic processes which may greatly militate against the safety of the patient; and he should in such cases omit no precaution which may tend to avert their destructive agency. Rigid antisepsis, or preferably, if it can be put into practice, rigid *asepsis* must be the motto; without it no such wound can be properly treated.

If instead of finding some portion of bone chipped off, or some foreign body embedded or loose, we find simply lines of cleavage indicating linear fracture, different lines of treatment should be pursued, according to what we judge the character and extent of the fracture to be. If symptoms of compression indicate internal hæmorrhage or protrusion inward of some bony fragment of the inner table, the relief of the pressure is called for, as will be subsequently considered when discussing the indications for trephining. If, on the other hand, no sign of intra-

cranial trouble be manifest, and no loose piece of bone demand removal, the case should be treated much as if no such serious lesion were present, save that the asepsis should be rigid, and absolute and prolonged rest be insisted upon.

It will be appropriate here to discuss the treatment of any severe contusion of the skull, which from the history of the injury or the inherent features of the case has in all probability produced some fracture of the cranial vault. Such a fracture is to be considered from the same point of view as a simple fracture of any bone, deriving special importance only when there is concomitant or subsequent injury to the cranial contents. Notwithstanding the internal table is often very extensively injured, many cases of simple depressed fracture proceed to permanent recovery without any active treatment and without alarming head-symptoms at any time in their course. But a few years ago it was the practice in all cases of simple fracture, whatever the depression, or however great the comminution of bone, to pursue a conservative line of treatment and to convert a simple fracture into a compound one by incision of the soft parts covering it, for the purpose of the application of a trephine or the removal of detached splinters of bone, only when prolonged or alarming symptoms of intracranial mischief rendered it imperative. The frequency with which intractable epilepsy has developed as a result of this policy has, however, rendered it entirely obsolete. A very slight depression of the skull which gave rise to no immediate symptoms, in after-years may be the cause of grave cerebral disturbances. Many of these cases have been operated upon at the end of varying periods of time, and the old depression relieved. The experience has been that the brain disturbances have been improved or entirely cured for a time; but there is a tendency for the symptoms to recur even after the depression has been entirely relieved. Although cases have been improved and some entirely cured by the late elevation of such depressions, the general experience with the operation is far from satisfactory. For these reasons, if for no others, any depression of the inner table of the skull, however slight, whether it gives signs of brain disturbance or no, should be immediately elevated. The results of the primary operation are eminently satisfactory; the results of the deferred operation are pre-eminently unsatisfactory. The presence of bloody exudate under the scalp, in the

case of simple fracture, often renders the diagnosis of depression difficult. When there is no depression present the softness of the area of hematoma beneath the scalp, and the sharp line of demarcation between this area and the surrounding normal scalp, gives to the palpating hand the impression of depression. When, however, there is a reasonable doubt, the surgeon should make an exploratory incision in due form to determine the absence or presence of depression. If none is discovered, the operation has evacuated the pericranial hematoma and done the patient no harm. "The injunction to refrain from interference with depressed fractures in the absence of complicating symptoms, however, is still widely upheld and respected in the profession, for no better apparent reason than the fact that many patients who are treated upon the expectant plan at least temporarily recover, notwithstanding the recognized dangers to which they are exposed. The influence of tradition and a failure to apprehend the changed conditions of modern surgery often content the general practitioner with the gambler's chance, and the patient takes all the risk." [Phelps: Traumatic Injuries of the Brain.]

It is wrong to attribute peculiar symptoms to fracture of the skull and to define certain cerebral disturbances as signs of fracture. Fractures of the vault of the skull have no peculiar symptoms, and they can be determined only by tactile or visual sense. Symptoms of compression, depression, and laceration of the brain, variations in pulse and respiration, stupor and changes in the pupils, are conditions which may or may not be associated with fracture. It has been shown that the symptoms of cerebral compression are the same whether due to depressed bone, to blood-clot, or to abscess, and confusion in diagnosis and error in treatment arise in enumerating these complications as symptoms of fracture.

Should destruction of soft parts be so extreme, should laceration be so extensive, that it seems best to remove more or less tissue, fearing that its vitality is lost, the surgeon need not hesitate to make a plastic operation to cover the defect, provided it seem advisable. And even if the bone have been denuded, nay, even if the dura mater be laid bare, as will happen after certain injuries as well as operative procedures, unless something else contra-indicate it, plastic operations may still be made.

The writer has repeatedly succeeded in making skin flaps adhere, *per primam intentionem,* to portions of the cranial vault whose external table had been removed; while surgical literature contains abundant reference, which coincides with personal experience, to cases in which they have adhered equally well to the dura mater.

In case of short fissure or circumscribed depression of the *outer* table the surgeon has but little to do beyond careful dressing, and may almost limit his use of instruments to the needle.

Should a sequestrum exist underneath a granulating mass, as may result during the course of some of these cases, it should be removed like a similar foreign mass elsewhere in the body.

Wounds are occasionally inflicted with saws, as in the following case related to the writer. A laborer in a saw-mill fell in such a way that his head was thrown against a saw in rapid motion. A clean cut was made through scalp, skull, and an uncertain distance into the brain; the line being along to one side of the superior longitudinal sinus. The man was at once removed to his home, and medical aid summoned; but there was very little to do, and he was treated symptomatically.

Considerable discussion arose as to what extent it would be proper to sew up the external wound, etc., and the home talent finding this too knotty a problem to decide called counsel from a neighboring city. But while the surgeons were discussing the *pros* and *cons* of this question the patient progressed rapidly, and by the time the matter was finally settled he was evidently out of danger.

Should the reader meet such a case, his best policy would be to abstain from any active interference, to shave the parts, to approximate the edges of the scalp wound, save at certain points for drainage. If any serious hæmorrhage were in progress the case would fall under the head of injuries to the vessels and sinuses of the cranium, to be considered in another paragraph.

Gunshot wounds are noted for the numerous splinters around the edge of the lesion they cause. These splinters, being loose or almost so, should be carefully removed.

It should not be forgotten that children have no frontal sinus, and that consequently the brain lies close to the front. Hence a fracture of the *os frontis* in children should not be indifferently probed, nor even

such an examination made as may sometimes be permitted in an adult, nor need it cause surprise if the dura mater seem very close to the surface.

Fistulous openings may remain long after injuries such as we have been considering have apparently or for the most part healed. Their treatment is the conventional one, *i.e.*, free exploration with removal of all débris or diseased bone.

Fractures of the Base of the Skull.—Fracture of the base of the skull is an injury, the great frequency of which has been realized only in recent years. The diagnosis is difficult, because of the impracticability of applying the visual or tactile test. In the light of recent studies it is now known that many cases heretofore diagnosed as cases of transient concussion have suffered with fracture of the base of the skull. This lesion is frequently associated with fracture of the vault, the lines of fracture being continuous one with the other. It is usually complicated with concussion. Symptoms of compression may also develop as a result of intracranial bleeding from the line of fracture. There is but one symptom which may in any way be regarded as pathognomonic: that is, the sign of bleeding from the fracture appearing from the ears, nose, mouth, or beneath the skin about the eyes or behind the ears. Often this oozing is composed of blood and cerebral fluid. In nearly fifty per cent. of the cases studied by Charles Phelps there was an absence of this symptom. There are two chief dangers in fracture of the base of the skull: hæmorrhage, causing compression of the brain; and, in the compound variety, or that opening into the nasal, aural, or buccal cavities, infection, causing meningitis. Fracture uncomplicated by either of these accidents is not to be regarded as a fatal, or even dangerous lesion. In order to diminish the danger of hæmorrhage the patient should be kept as quiet as possible. Bromides, chloral, and morphine may be freely given. If the fracture is continuous with or associated with a fracture of the vault of the cranium, the head should be immobilized by a posterior cuirasse, which may be made of plaster-of-Paris bandage material, extending over the head, neck, and back. In order to minimize the danger of infection, the nose or ears, or whatever cavity is seen to be connected with the fracture, as evidenced by the sign of bleeding, should be rendered as clean as possible. This may be accomplished by frequent

irrigations with antiseptics, such as boro-salicylic solution, or formaline and thymol, for the nose. The value of plugging the ears or nose with iodoform gauze after irrigation is questionable. It is held by some surgeons that it is useless to attempt to disinfect the nasal cavities by irrigation. We concede that antiseptic irrigation of the nose does not completely sterilize that cavity, but we do insist that it removes the excess of micro-organisms, washes away the secretions, and provides for better drainage. The greatest revolution of our surgical art has been accomplished upon the grounds of partial sterilization.

The balance of the treatment must be symptomatic and largely medicinal. The bowels should be thoroughly moved. If collapse be imminent, local and general stimulation in moderation, not to excess, lest with too vigorous reaction come undesirable consequences. When once the pulse and respiration are satisfactory, and the bowels cleared out, the rest must be left largely to time. Ice applications to the head may be indicated—will be, in fact, if temperature rises or meningitis occur. Artificial nourishment will be required as unconsciousness or a paralysis complicate the case. This may be administered by the long tube either into the stomach or rectum, as seems best.

TREATMENT OF INTRACRANIAL HÆMORRHAGE.

One of the most difficult questions which the surgeon is called upon to decide is that as to the advisability of operating for hæmorrhage which is believed to have taken place within the cranial cavity. In this work we have to do chiefly with hæmorrhage from fractures of the skull. In compound fractures with loss of bony tissue the surgeon should remove the blood-clots which he finds beneath the skull. In simple fractures he can only know of the presence of such hæmorrhage by the symptoms which its presence gives. And, finally, he often has to deal with cases in which the symptoms of fracture are absent, but in which the signs of intracranial hæmorrhage are present, and upon the strength of which he assumes the presence of a fracture. The blood in these cases usually comes from the diploë or from the vessels which ramify between the bone and the dura mater. It spreads itself out upon the dura, forming a clot, thickest at its centre and thinning out toward the periphery.

This clot gives rise to symptoms varying with its size, location, and rapidity of development. The symptoms and the signs of localization will be found described in works on brain-surgery. In general it may be stated that the signs which may guide the surgeon in determining the presence of such hæmorrhage are the symptoms of brain compression or diminution of the size of cranial cavity, stupor, slowing of the pulse rate, dilatation of the pupil on the affected side, and the localizing signs dependent upon the particular part of the brain compressed. For obvious reasons such compression should be relieved. Operation should not be done until the patient has recovered from the immediate shock of the traumatism. On the other hand, if the symptoms of progressing hæmorrhage are present, as evidenced by gradually deepening stupor, etc., further delay may be fatal. Here the surgeon is called upon to exercise that nicety of judgment which must come largely from experience with this class of cases, and from an accurate mind-picture of the pathological conditions before him. Usually the location of the fracture determines the location of the bleeding; or, if a fracture has not been discovered, the place of contusion of the scalp may be the guide. At any rate, the presence of a compressing clot having been assumed and operation determined upon, the skull should be opened by the methods of elevation of fragments already described, or by the operation of trephining as set forth below. The following case will serve to illustrate: A lad fourteen years of age was struck over the middle of the right parietal bone with a base-ball bat. He remained unconscious for a few minutes, after which he developed stupor. This gradually deepened, and for three days he lay in a state of semi-consciousness, from which he could be aroused with difficulty. He was then brought to the hospital and came under the writer's care. There was no wound of the scalp and no depression of the skull. A hematoma of the scalp marked the site of the traumatism. After proper preparation, this area of contusion was exposed by a curved incision, and the blood beneath the scalp was evacuated. The flap was turned down, and several radiating lines of fracture were discovered. The skull was trephined, and a clot the size of the hand was exposed. The opening in the skull was enlarged, and the clot, which was closely adherent to the dura, was removed. The hematoma of the scalp and that beneath the skull had both originated from the broken bone. On the following day

the stupor had almost subsided, and by the end of forty-eight hours the patient had been restored to an entirely normal state of mind.

An accumulation of sero-sanguinolent fluid sometimes takes place between the dura and the brain in cases of fracture of the base of the skull. Symptoms of compression from this cause may be relieved by trephining and incising the dura. A case of this sort has come under the observation of the writer, in which, after a fall from a height, a man gradually developed stupor and signs of compression of the brain with right-sided pressure. The pulse rate gradually decreased till it had gone down to 48 per minute. The scalp showed no sign of traumatism. There was no fracture of the vault of the skull. The dura was exposed by trephining over the right motor area and incised. Bloody serum welled up from the direction of the base of the brain. A smaller trephine opening for drainage was made lower down. From this opening bloody serum freely escaped during the first twenty-four hours. The pulse rate went up to normal, and the stupor had entirely subsided within thirty-six hours after the operation.

THE OPERATION OF OPENING THE SKULL.

The artificial exposure of the brain or the meningeal spaces is accomplished, (1) by elevating and removing loosened fragments of the skull, (2) by cutting a circular hole through the skull with the trephine, (3) by sawing out an area of bone with a circular saw, (4) by chiselling out a piece of bone with chisels especially adapted for that purpose, and (5) by elevating, but not detaching, a valve-shaped fragment. When possible, the bone should not be entirely removed, but should be left attached along one side and turned back as a flap, so that it may be replaced at the conclusion of the operation. Thus, if the skull is to be opened by any of the above-mentioned methods, with the exception of the trephine, one side of the bone valve is left attached, and as the flap is turned up the segment is fractured across its base. The choice of these methods must depend upon the peculiar conditions of the particular case. The operation of trephining has been given a special place among surgical procedures and voluminously discussed. At the pres-

ent day we attribute no especial or peculiar importance to the use of this instrument. It is employed to fit the exigencies of a case, and has nothing to do with the determining of the ultimate outcome, as one might suppose from reviewing the statistics of cases embodying those trephined and those not trephined. It is a simple instrument in the hands of the surgeon for performing a simple operation, which he may use when it serves his purpose better than the bone forceps, elevatorium, chisel, or saw.

The indications for opening the skull which come within the scope of this work are: (1) fractures with depression, (2) fractures with pressure, producing intracranial hæmorrhage, (3) intracranial hæmorrhage without fracture, (4) foreign bodies within the cranium, (5) for the evacuation of pus from the meningeal space or from a deeper abscess, (6) for the removal of serous fluid from the meningeal or ventricular spaces, and (7) for exploratory purposes.

If the patient is in a condition of stupor or coma an anæsthetic need not be used. The scalp should be shaved and cleansed according to the rules already laid down, and the head rested upon a firm sand-bag. The bone is best exposed by a wide curved incision and the flap of scalp turned back, unless the bone is to be left attached to the flap, in which case it is not turned back until the bone segment has been freed. If the skull is to be opened by means of the trephine the surgeon proceeds as follows: The centre pin is made to enter the bone and the instrument rotated until the teeth have cut a circular groove. The central pin is then removed. The instrument is then worked until a button of bone has been cut out. The rotation should be practised carefully and from time to time the trephine should be withdrawn to brush the bone-dust from its teeth. By percussing the edges of the button with the handle of the instrument the firmness of its attachment may be determined. Complete division of the outer table and entrance into the diploë will be recognized by the more yielding sensation to the hand guiding the instrument, and the altered, more bloody character of the detritus thrown up by the saw. The surgeon must never forget that children and aged persons have no diploë, their crania being therefore so much the thinner. As the instrument is made to cut more deeply it must be the oftener withdrawn and the groove explored with a blunt probe, by which one will

be able to distinguish between the bone and the more elastic and yielding dura mater. If the probe go through on one side, he must be very careful to press the trephine only on the other side, and to avoid lacerating the dura with its teeth. Extreme caution is now required. On account of irregularities of the inner surface of the skull it may be impossible to cut everywhere through the whole thickness of bone without endangering the parts beneath. In this case, even at the risk of causing spiculæ of bone, the disc must be broken out.

The trephine having been carried as far as deemed judicious, one end of the elevator is inserted under the disc, and with the margin of the sound bone as a fulcrum it is pried out of place, the elevator point being introduced at several points around its circumference if need be. When loose from bony attachments the elevator and the forceps will facilitate its removal. Sometimes the combined action of two levers may be necessary.

With this removal of a disc of bone the prime object of the operation is attained, and pus or blood may be evacuated, or depressed portions of bone may be raised to their proper level by prying them with the elevator. Before closing the wound all sharp points should be removed and rough edges smoothed off with suitable instruments. If a coagulum is to be extracted it may be broken down with the bent probe and washed away with a stream of tepid water. It is a favorable sign when the dura rises in proportion as clot is removed.

In cases of comminuted fracture it may be possible to remove the fragments with the elevator and forceps, without the necessity for making a prior opening. Sometimes a projecting piece of bone may be removed with a saw or forceps.

Points to which the Trephine should not be Applied.—The line of the longitudinal sinus, the occipital bone over the course of the large sinuses, and only for special reasons should the skull be opened over the middle meningeal artery. A point an inch and a quarter, or half, back of the external angle of the orbit marks the site of the artery. If necessity arise for application of the trephine over the frontal sinus, the outer table should be first removed and then the inner.

Should the circumstances of the case, the bulging of the dura mater and its discoloration, lead to the supposition that pus or blood be present

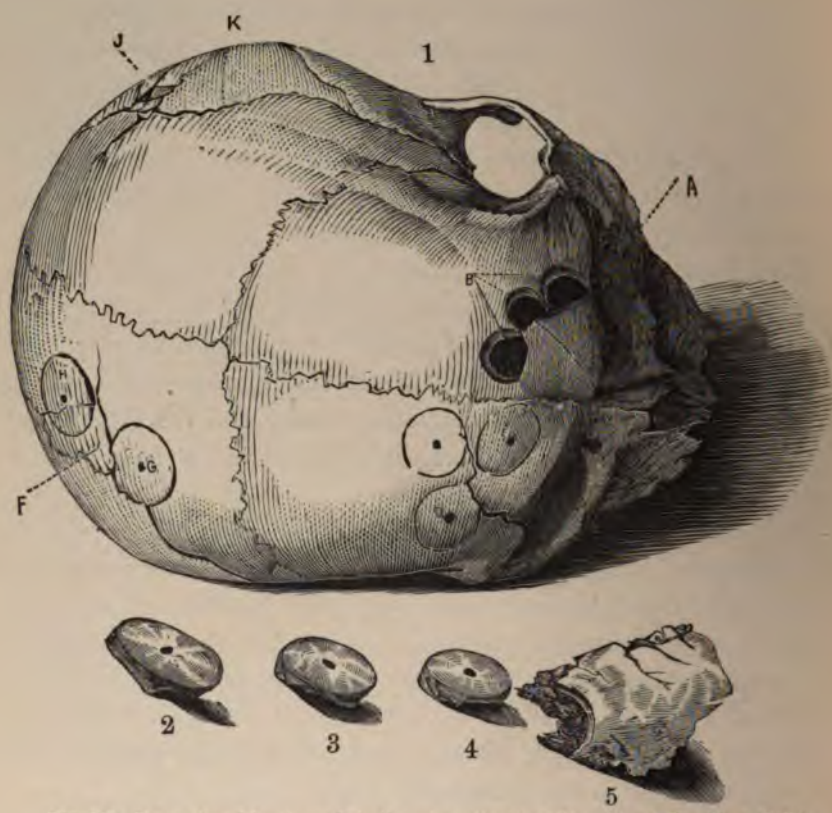

FIG. 112.—Examples of fracture of skull, and application of trephine (after *Chas. Bell*).

1. A skull showing various examples of fracture. A, a triangular portion of the os frontis, fractured and depressed. B, the three perforations found necessary for its elevation and extraction. The edge of the inner table being found to shelve under the sound bone made the second and third perforation necessary. This was a mistake, but one which may happen. D, a point where the trephine was employed for a fissure and fracture of the os frontis represented at its right side; a second perforation was made on the sound bone a little higher up, still the bone could not be extracted; the trephine was then applied at E, and the bone lifted up. It should have been applied at E in the first place. F is a fracture with depression at the lower angle. The trephine was placed at G. It ought to have been a large one, and placed at H, by which a portion of bone would have been saved and a more favorable form of opening obtained. By perforating at G an acute angle of bone was left between G and F.

4. The button of bone removed in order to elevate the fragment represented in 5. Here, by careless work, the surgeon might have pressed on the depressed portion with the trephine, and thus depressed and chafed the dura.

2 and 3. Buttons of bone having inequalities on their lower surfaces, showing the necessity for extreme caution during the operation.

FIG. 113.—A fractured skull after the application of the trephine and the removal of the fragments (after *Chas. Bell*).—Scalp not shaved gives false impression.

1. Shows the parts after the application of the trephine and removal of the fragments. A, B, the flaps of integument; C, the cranium; and D, the dura mater exposed.

2. Sketch of the fractured bone. A, B, C, the three portions of fractured bone, with depressed edges, which, being sharp, are irritating the dura; they must, therefore, be removed. They are, moreover, so separated from their attachments as to have lost their vitality. There being no "purchase" for the elevator, the trephine is applied at D, and the broken pieces elevated and picked away.

3. Two discs of bone cut by the trephine, showing the varying thickness of the skull.

4. Exfoliation of bone after use of the trephine.

5. Shows the two tables of the skull, with the diploë between.

beneath it, it would then be right to incise it and remove whichever might present.

Whenever removal of one disc proves insufficient for the elevation of bone or removal of clot the surgeon is justified in removing a second and a third, or continuing the operation with the chisel, bone-forceps or saw.

ENLARGING OPENINGS IN THE CALVARIUM.

For the purpose of enlarging openings which already exist in the bones of the cranium for the elevation of depressed fragments, the ex-

FIG. 114.—Biting off the edge of bone, in a fracture of the skull, with gouge-forceps (*Esmarch*).

traction of splinters of bone or foreign bodies, and to provide for the adequate cleasing and drainage of penetrating wounds of the skull, gouge-forceps may be conveniently used, by means of which the edges may be gnawed away, and the opening quickly enlarged in any direction. The sawing out of a circular piece of bone by the trephine need be resorted to only in those cases in which there is no opening in the skull. If there is but a narrow fissure which has to be widened, a gouge and a wooden mallet may be used, with which small, sharp blows should be dealt upon the chisel obliquely placed upon the bone. When the opening has been sufficiently widened, the gouge-forceps can be used for its further enlarging, as may be necessary.

In closing these wounds the dura, if lacerated or cut, should be sutured with fine catgut. The periosteum should always be preserved, and, when the bone is not replaced, sutured over the opening. As to the replacing of buttons and fragments of bone, a discussion of this question will be found in the chapter on the wounds of bone. The scalp should be sutured according to rules already laid down.

These wounds most often involve the longitudinal and transverse sinuses and the middle meningeal artery. It occasionally happens that these are injured during the operation of trephining or resection of bone. If by a small penetrating wound a superficial sinus be punctured, a gauze

FIG. 115.—The use of the gouge and mallet to enlarge an opening in the skull (*Esmarch*). The cuffs and coat shown in this cut indicate the preantiseptic date of its preparation.

tampon may be sufficient to check bleeding. The cases are numerous in which rapid recovery has followed this simple measure. Death is in such cases unusual, and results rather from other complications, such as injury to the brain, or partial escape of blood into the cranial cavity, or from septic processes. Genzmer[1] has related a fatal case from Volkmann's clinic of entrance of air into a sinus during extirpation of a sarcoma from the bone and dura mater. But under most conditions this would never happen. Wounds of the cavernous sinus through the orbit have been peculiarly fatal.

[1] *Verhandl. d. deutschen Gesellschaft f. Chirurgie*, 1877, ii., 32.

When a splinter of bone or a foreign body has perforated a sinus wall the blood may escape at once or only after its removal. These cases are rare. The hæmorrhage may be checked by tampons, or by forcipressure, or the sinus walls may be sewed together, as in the following case reported by Parkes,[1] of Chicago. In June, 1882, he was called to treat a man who had received a compound comminuted fracture of the skull, with depression; the fracture was just in front of the middle of the sagittal suture, extending into and involving the right parietal bone. The depressed portion was fully an inch in its longest diameter, and extended a little to the right of the median line. He had paralysis of left side, but no head symptoms. An anæsthetic having been given, Parkes endeavored to remove the fragments. After removal of two or three a terrific hæmorrhage set in, so that he was compelled to occlude the opening by a pad of gauze. Next morning he removed the compress and found the hæmorrhage to at once recur. As rapidly as possible he removed the fragments, exposing the dura mater, when he found a large opening in the upper wall of the longitudinal sinus, from which the blood poured in a stream. He packed the opening with sponge, and, clearing out all débris, smoothed off the roughened edges of bone. Finding the dura entire, with above exception, he removed the sponge and united the edges of the rent with three fine catgut sutures. Bleeding was checked at once, and the man made an excellent recovery. The opening in the sinus was as large as a coffee-bean.

If complete circular ligation of the longitudinal sinus on either side of a wound should be indicated, the tightening of the ligature should be preceded by sufficient separation of the outer wall of the sinus from the skull, or by incisions into the dura mater parallel and near to the sinus, so that the walls of the sinus may readily fall together, otherwise the ligature will cut the tense walls of the sinus, thus precipitating anew a copious bleeding, or the "reef" in the dura caused by the ligature will so depress it below its normal position, with increased tension, as to compress to an undesirable degree the cerebral cortex (Stratton[2]).

These wounds of sinuses usually heal well, with only a thickening of

[1] Annals of Anatomy and Surgery, 1883, viii., 118.

[2] Annals of Surgery, August, 1898.

the walls; but entire obliteration of a single channel is of no great import, as Schellmann's researches[1] have shown. The principal danger comes from the infection of thrombi.

Many cases of penetrating wound, injuring the middle meningeal artery, have been reported. It has several times happened that this vessel required ligation during removal of fragments after severe injury; while during our civil war the common carotid was seven times ligated for this same purpose, with three recoveries. When gradually increasing symptoms of compression lead us to fear a rupture of this vessel, although there be no open wound, the skull should at once be opened and the vessel secured if found to be injured.

Injuries to the cerebral portion of the internal carotid are much rarer than those to the meningeal. Longmore relates that a bullet penetrated, in one case, through the orbit into the petrous bone and lodged there, but led to erosion of this trunk and fatal hæmorrhage. Some injury of this kind might, if not rapidly fatal, lead to the formation of an arterio-venous aneurism calling for ligation of the common trunk.

The treatment of wounds of vessels in the substance of the brain cannot differ from that already laid down. When hæmorrhage in the subdural space is diagnosed, it is good practice to trephine and open the dura. The diagnosis and location of intracranial apoplexies is one of the triumphs of modern surgery, and its full consideration will be found in works upon that subject.

INJURIES TO CRANIAL NERVES.

The treatment of injuries to these nerves inside the cranium cannot be other than symptomatic. Should a depressed fragment or a foreign body press upon a nerve-trunk, removal of the same would meet the principal indication, and, provided the injury were not too severe in other respects, the nerve might regain more or less of its function. When it is certain that a nerve-trunk outside the cranium is severed, it may be dissected down upon and united with a fine catgut suture, just as should be done elsewhere in the body.

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[1] *Ueber Verletzung der Hirnsinus;* Dissertat., Giessen.

WOUNDS OF BRAIN SUBSTANCE.

Inasmuch as these are usually complicated with those of parts external, we can draw no abrupt therapeutical distinction. Obviously, if aseptic measures are indicated for more superficial injuries, they are vitally essential here. We wish to emphasize, also, more fully in this connection, what has already received mention in this work, and that is, the futility—we are almost tempted to say the homicidal effect—of careless or ineffectual probing for bullets, since most of these wounds are made by projectiles. The array of cases set forth by German military surgeons, in which most dangerous wounds, such as when treated by old methods of promiscuous bullet-hunting, were surely fatal, primarily and antiseptically occluded, and never probed nor investigated, have gone on to speedy recovery—this array should be most convincing as to the merits of this practice.[1]

Probing disturbs clots and all reparative effort, and too often introduces septic organisms into deep parts. Suppose we know a bullet has entered a head, and are able to follow its track with a probe two inches deep into the brain, what good have we accomplished, what valuable knowledge gained? We knew that it had penetrated; we could have made a guarded if not a grave prognosis without the probing; we have gained nothing, but, on the contrary, may have introduced new and disturbing elements. The practice, then, which will commend itself is the following:

If, after a gunshot or small perforating wound, the missile not being found immediately at the place of entrance, there be no symptoms indicating a serious hæmorrhage or compression or localizing symptoms, the treatment is most simple, and consists of aseptic cleansing and occlusion of the external wound, cold applications to the head, free evacuation of the bowels, and absolute rest. The occlusion should be made with simple iodoform gauze, or something of the kind. If, after the lapse of hours, symptoms of compression or intracranial lesion supervene, then the trephine will be called for. The Roentgen ray may be used to aid in the localization of the bullet. Peculiar bullet probes have been con-

[1] *Vide* Annals of Anatomy and Surgery, 1883, vii., 114.

structed for this purpose, but their value in searching for bullets within the cranium is questionable. If, on removal of the disc of bone, it shall appear that depression caused the trouble, after it is relieved no further operation is needed. If a clot be found between dura and skull it should be carefully removed, if necessary by removal of more of the bone. If a pouting and dark appearance of the dura make it probable that there is subdural hæmorrhage, an incision through it should be made, and blood removed as before. If, during these manipulations, the foreign body be recognized, it would be well to remove it as gently as possible; but the circumstances must be very rare which shall justify random exploration in the brain for a bullet. Moreover, many recorded cases prove with what apparent freedom from serious consequences patients may recover with such foreign masses as bullets in their brains. Not a few men are to-day at work, who are known to be carrying some small mass of lead embedded in their brains. The safest rule to follow, then, is to *abstain from all operative measures when the indications become obscure.*

HERNIA CEREBRI.

When from a recent wound, or one of a few days or weeks' standing, protrusion—*hernia cerebri*—takes place, it may seem doubtful whether it would be better to excise the protruding mass or to endeavor to replace it by suitable pressure. Of course the careful surgeon will suture the dura mater, close the wound and dress all fresh cases with such a judicious amount of pressure as shall guard against this condition; but he may be called on to treat it after it has happened. If the hernial mass has commenced to slough, there can be no question; excision must be practised and hæmorrhage carefully watched for and checked; twisting or tying any little spouting vessel—pressure, or the not too hot cautery on oozing points, will usually govern this. When the mass appears healthy, gentle but continuous pressure will usually cause the disappearance, within the cranium, of its proper contents. If this cannot be accomplished during the time of an ordinary dressing, compresses and bandages should be arranged so as to exert an unintermitting pressure. After reduction a prothetic plate may be adapted to the shape of the part

and applied externally as a portion of the bandage-technique. Cauterizing or ligating the protruded mass is almost as dangerous as excising it.

Adams has reported a case of irreducible hernia cerebri, in which he succeeded in covering the hernial mass with a flap of skin by a plastic operation,[1] and Kusmin another similar, except that he resorted to skin grafting.[2]

WOUNDS DURING BIRTH.

With reference to those injuries to the fœtal head which may happen during natural or artificial delivery, it is necessary to add but little. Even large extravasations of blood are usually absorbed; in extreme cases, after waiting a few days, it is well to incise them and turn out the clots. Excoriations and bruises made by instruments need only conventional treatment. Fatal phlegmonous inflammation has been known to result from such injury done by forceps, hence the necessity for asepsis and attention to detail. Symptoms arising from the compression caused by the forceps will usually subside as the head resumes its shape. Should fracture take place, it must be treated upon the general principles laid down.

BANDAGES FOR THE HEAD.

Apposition of wound-surfaces, compression, and the retention of dressings in their place require much ingenuity in the application of proper bandages in the case of head-injuries. The following figures, from Esmarch's Handbook, will serve to indicate those methods of bandaging most likely to be of service.

The *double-headed roller* (Figure 116) is applied by placing the centre of the bandage opposite to the seat of injury, and carrying the two heads past each other with gradually increasing traction upon the wound; these turns are then brought back again to the starting-point, and the same process repeated several times.

The *sagittal bandage* (Figure 117), a T-bandage, is especially suitable for transverse wounds of the scalp.

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[1] Lancet, 1876, No. 11.

[2] St. Petersburg. *Med. Wochschft.*, 1878, No. 17.

The *halter bandage* (Figure 118). The first turn begins on the top of the head, crosses the cheek by passing under the chin, and returns to the

FIG. 116.—Double-headed roller.

FIG. 117.—Sagittal bandage.

FIG. 118.—Halter bandage.

FIG. 119.—Capelline bandage.

FIG. 120.—Four-tailed cap for the vertex.

FIG. 121.—Four-tailed cap for the occiput.

vertex. From here the second turn runs backward round the occiput; it is then carried from the nape of the neck to the front, round the an-

terior surface of the chin; lastly, it returns to the nape of the neck, and ascends again to the vertex. After these have been repeated two or three times, the third turn brings it to a conclusion by forming a circle from forehead to occiput.

The *capelline* (Figure 119) is a double-headed bandage, the end of which passes round the head from forehead to occiput, and fixes the turns of the other end, which is carried alternately over the right and left parietal bone, each turn overlapping the preceding one.

The *four-tailed cap* (Figures 120 and 121) is a rectangular handkerchief, three times as long as broad, and slit at its narrow ends. The figures show the method of its use.

WOUNDS OF THE FACE, ETC.

Wounds of the eye are usually relegated to the specialist in that department, yet it is essential that every practitioner should at least know what "first help" to render. No careless efforts should be made to remove penetrating particles or bodies, but the eye should be carefully cleansed with a 1:50 solution of borax, a few drops of a 2 to 4 per cent. solution of cocaine may be instilled to allay pain and irritation, the eye should then be lightly dressed with a compress saturated with boracic solution, and the patient kept quiet. For further information the reader is referred to the standard treatises on ophthalmology.

Wounds of the interior of the ear should first be treated with warm boracic solution. If pain be extreme, a few drops of a solution of morphia, with a little atropia in glycerine, may be instilled. Beyond this nothing but hot water, made antiseptic, and possibly alkaline, should ever be used except by direction of the aurist.

Incised wounds of the eyelids may be united like other wounds. The approximation should be as neat as possible that the resulting scar may be slight. Fine silk should be used.

A variety of *penetrating wounds of the face* may be met with. If no vessel be severed, repair usually goes on speedily. The less such a wound is disturbed, as by probing, the better. A pad of antiseptic gauze bound on, or occlusion made by iodoform collodion, will probably be all sufficient. If compression do not check hæmorrhage a deep stitch on either

side the opening may be resorted to. If serious hæmorrhage indicate the division of some arterial trunk, the wound must be enlarged enough to permit application of a ligature to each end of the divided vessel, or possibly a ligature below the wound may be required.

Should fracture of the nasal bones complicate a case, the parts may be supported by tampons of gauze from within the nose, or, according to the method recommended by Mason,[1] they may be supported upon a strong needle passed under them from one side to the other. Should severe epistaxis occur, it is best controlled by plugging the nostril with gauze.

In any of the great variety of gunshot wounds that may occur, the rule should be as follows: If no serious symptoms indicate a lesion incapable of spontaneous recovery, a simple antiseptic occlusion of the wound will be all that is required. Any symptom of really grave import can be recognized without the probe. Should, on the contrary, the general and particular features of the case indicate some operative measure, all probing and investigating should have been omitted until then, when all can be done at one sitting and with better results.

The same will hold good with regard to injuries by larger or foreign bodies, as *e.g.*, fragments of glass, bombs or shell, or splinters of wood. Primary antiseptic occlusion on the battle-field, or place where injured, and all operative measures later when they can be carefully attended to.

Intractable bleeding sometimes occurs after extraction of teeth, especially in so-called "bleeders." In these cases it is best to pack the cavity with gauze, and then make compression by stuffing that side of the mouth and binding the jaws together.

It may be possible to replace a tooth that has been wrenched or knocked out of its socket, provided the alveolar process be not badly broken, and to fasten it by wire or silk to other teeth or by binding the jaws together.

When fracture of any of the larger bones of the face occurs along with an external wound, making a compound fracture, the general rules governing the treatment of such injuries should be observed;—approximation of fragments, perhaps by wire or chromic catgut, disinfection of

[1] Annals of Anatomy and Surgery, 1881, iii, 107, 197.

the entire wound, provision for drainage, accurate adaptation of superficial wound, and suitable inter-dental or external support.

In wounds cutting through the entire thickness of lip or cheek it should be the effort to coapt the surfaces of mucous membrane as carefully as those of the integument. Otherwise there are no particular indications about wounds of the soft parts of the face or external ear differing from those in other parts of the body. If, however, the surgeon particularly desire to avoid scarring, he may do as Pancoast has suggested with reference to incisions made during plastic operations about the face—he may take a little more time and *bevel the edges,* so that one shall tend to lap or slide a little way under the other, thus making the cicatrix a mere linear one. The subcuticular suture of fine linen or silk thread is particularly adapted to the suturing of wounds of the face with the view of securing the best cosmetic results.

We may add that portions of the cartilaginous part of the external ear which have been entirely removed may be replaced, provided not too long an interval have elapsed, with expectation of reunion in quite a large proportion of cases.

Wounds of the Mouth.[1]—Wounds opening into the buccal cavity, as after extirpation of the tongue, etc., should be lightly packed with iodoform-gauze. The gauze, cut in strips, should be brought into intimate contact with the wound-surfaces, so as to fill all fissures and recesses. In wounds to which the gauze cannot be thus applied, as, for example, those of the throat and palate, the parts should be kept clean by frequent washing of the mouth with bland antiseptic solutions. Drainage is called for only after extirpation of the tongue and other wounds involving the floor of the mouth, in which there is already an external opening. Parenchymatous hæmorrhage is controlled by the gauze.

The gauze may remain *in situ* eight to fourteen days, till it is spontaneously detached. It is best, however, to renew the superficial layers of the gauze whenever they become saturated with saliva or discharges.

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[1] Wölfler: *Wundbehandlung im Munde, Archiv für klinische Chirurgie,* xxvii., 419. Hacker: *Anleitung zur antiseptischen Wundbehandlung,* p. 31.

CHAPTER XX.

WOUNDS OF THE NECK AND OF THE THORAX.

Wounds of the Larynx or Trachea—Punctures—Longitudinal Wounds—Transverse Wounds—Suturing the Trachea—Antisepsis—Tracheal Canula—Intra-tracheal Polypi—Hæmorrhage into Trachea—*Wounds of Pharynx or Œsophagus*—Swallowing Interdicted—Œsophageal Tube—Primary Importance of Deep Union—Longitudinal Wounds—Gunshot Wounds—Transverse Wounds—*Wounds of the Great Vessels of the Neck*—Arteries—Vertebral Arteries—Internal Jugular Vein—Lateral Ligature—*Wounds of the Thoracic Duct—Non-penetrating Wounds of the Thorax*—Wounds of Internal Mammary and Intercostal Arteries—*Penetrating Wounds of the Thorax*—Heart and Pericardium—Lungs—Pleuræ—Hæmothorax—Pneumothorax—Emphysema—Empyema and Hydrothorax—Résumé.

WOUNDS OF THE NECK.

THE wounds of the neck which present peculiarities that demand special examination are those deep wounds which penetrate the larynx or trachea, the pharynx or œsophagus, or involve the great vessels of the neck.

WOUNDS OF THE LARYNX OR TRACHEA.—Simple punctures of the air-tube, as in cases of stab-wounds, usually unite by first intention, without introducing any complication in the course of the more superficial wound. Spontaneous apposition of the edges of longitudinal wounds of the trachea may be depended on by reason of the resistance to separation exercised by the cartilaginous rings of its wall. The closure of such a wound by primary adhesion is the rule. Transverse wounds may be made to gape by extending the neck. In such cases the head should be depressed toward the chest sufficiently to bring the sides of the wound in contact, where it should be kept either by the occipito-sternal handkerchief of Mayor (Figure 122), or by some other apparatus acting on the same principle. Coaptation of the tracheal wound, in transverse wounds, may be assisted, if the case seem to require it, by introducing sutures through the peritracheal fascia, that ensheathes the tube; this peri-

tracheal fascial sheath has sufficient body to make its suture in such cases a valuable resource in making accurate adjustment and in steadying the wound-edges in their proper relations to each other in those comparatively rare instances in which the trachea or larynx has suffered transverse division through a large part or the whole of its circumference. If catgut is used for such a purpose, it should be cut off short in the wound. If silk, one end should be brought out through the superficial wound, and the suture regarded in the light of an ordinary ligature.

Close approximation of the more superficial wound-surfaces, and their suturing, should not be practised to a degree that would embarrass

FIG. 122.—Occipito-sternal handkerchief for approximating transverse wounds of the neck.

the free escape of any air, or mucus, or blood, that might be forced out of the trachea through the wound in its wall by cough or in ordinary expiration. Approximation, with efforts to obtain primary union, should, however, be made of all portions of the wound, with the exception named.

The entrance of infection into wounds involving the air-tube cannot be prevented, so that vigilant effort is required to antidote its effects. The free escape of all secretions should receive careful attention that it be perfectly secured. As an antiseptic application, iodoform, or any of its substitutes (page 86), may be used. By their use, the secondary su-

ture may be employed later with the result of shortening greatly the period of repair in favorable cases.

In cases in which there is considerable loss of substance of the wall of the larynx or trachea, great care must be exercised to prevent the entrance into the trachea of septic secretions. One of the most frequent and fatal complications of such injuries, as well as of similar injuries of the mouth, is broncho-pneumonia, from the inhalation of septic matters from the wound. For the prevention of such a complication, a suitable canula should be kept in place in the tracheal opening, and the surrounding wound-cavity should be kept packed lightly with iodoform-gauze, until its cicatrization is well advanced. The use of a similar canula will also be required for purposes of respiration, if that portion of the air-tube above the wound should become stenosed from any cause, as inflammatory œdema, diphtheritic exudate, or cicatricial contraction.

The opening of the canula should be kept covered by a moist and warm sponge to purify and moderate the temperature of the inhaled air, and thus to guard against bronchial irritation from cold or dust-laden air.

Exuberant granulations, forming polypoid excrescences projecting into the trachea, not infrequently form at one angle of a wound in the trachea which has been kept distended by a canula. They are formed by the excessive development of the granulations, which spring up to fill in the angles of the tracheal wound not filled by the canula. Their presence may be a source of dangerous embarrassment to the respiration when the canula is removed. They should be destroyed by the application of caustics, or by avulsion, followed by cauterization of their bases. Whatever operative procedure may be necessary to make them accessible to the required applications should be done. Whenever a prolonged use of a canula is required, watch should be kept for any signs of their development, and their growth repressed from the first.

The escape of blood into the trachea, to the extent even of producing suffocation, is a complication that should not escape the thought of the surgeon in the cares which he gives to the wound. It is to be prevented by thoroughness in the primary hæmostasis, and by the non-closure of the external wound. When blood in any quantity has already been poured into the trachea, it should be removed at once by forcibly com-

pressing the chest while the patient is held with head and neck hanging down, and by the introduction of forceps, armed with sponges, into the trachea through the wound, which may be enlarged, if necessary, to admit of being cleansed. A syringe, if at hand, may also be used to suck out the blood.

WOUNDS OF THE PHARYNX, OR THE ŒSOPHAGUS.—The pharynx, or the œsophagus, may be wounded from within, or from without. In the former case, portions of the ingesta, in the act of eating or drinking, may escape into the connective-tissue of the neck, and produce purulent infiltration of its loose substance. If the wound is in the posterior wall of the tube, the suppurative gatherings may burrow into the posterior mediastinum below. These dangers, and the requirements of "rest" for the wound, make it necessary that the functions of the canal in swallowing food shall be held in abeyance for a time. The patient must fast for the first days, until adhesion of the wound-edges has taken place. He should be sustained by nutritive enemas, which alone may be sufficient to sustain him during the period required. Great thirst may be alleviated by rinsing the mouth with lemon-juice or ice-water, but all attempts at swallowing should be rigorously interdicted. If the rectal alimentation be insufficient or impracticable, a flexible tube should be introduced into the œsophagus to a point beyond the wound and nutritious fluids be supplied to the stomach through this. Such a tube, introduced through the nose, has been left *in situ* for a long time, and the prolonged support of the patient successfully accomplished through it. This physiological rest of the œsophagus should be observed in all wounds of its walls. Cases in which a wound from without has reached and opened the pharynx or the œsophagus are less liable to be attended by phlegmonous infiltration of the tissues of the neck, or by other septic accidents. The wound in the alimentary canal is, or, in many other cases, may be made accessible to treatment to secure its primary union, and the external wound, by the drainage that it affords, is a safeguard against the retention of irritating matters.

The chief end to which treatment must be directed is to secure, first, union of the wound in the pharyngeal or the œsophageal wall. A simple longitudinal wound, as that inflicted in the operation of œsophagotomy, presents little difficulty. There is no tendency to gaping, coaptation is

spontaneous and perfect as long as no attempt at swallowing food is made, the external wound is approximated and treated according to the requirements of incised wounds in general, and primary union results.

Gunshot wounds of this tube do not admit of primary antiseptic occlusion. They should be treated by enlargement of the external wound, and adequate provision for free escape of wound-secretions and débris from the deeper parts of the wound. Drainage tubes should be used, and the wound, after thorough primary disinfection, should be kept lightly stuffed with iodoform gauze and be made to "heal from the bottom."

Transverse incised wounds should be sutured, whenever the wound in the tube is accessible, or can be rendered so by a proper enlargement of the external opening. Catgut will make the most convenient material for the suture. The sutures should not include the mucous membrane, but only the submucous and muscular coats. The interrupted form should be used, and the intervals should be small, not exceeding the fourth of an inch. They should be cut off close. The external wound should be cleansed and disinfected, and approximated with a view to secure union by first intention throughout. The head should be kept in a position to relax the wounded structures and prevent gaping.

Wounds of the Great Vessels of the Neck.—*Arteries.*—Should either of the main arterial trunks of the neck be wounded, the rule to expose the wounded vessel and to ligate it above and below the wound is imperative. If large collateral branches be cut, the same rule should be followed, if practicable, and the practicability of the procedure will largely depend upon the anatomical knowledge and the operative dexterity of the surgeon. The following comment on the subject of hæmorrhage and ligations in wounds and injuries of the neck occurring during the War of the Rebellion is by its surgical historian.[1]

"Grouping the ligations of the large vessels of the neck, performed on account of gunshot wounds of the face or of the neck, we have a total of seventy-five ligations of the common carotid, with a mortality of seventy-eight per cent. . . . Nowhere else, not even in wounds of

[1] Otis: Med. and Surg. History of the War of the Rebellion. Part I., vol. ii., Surgical History, p. 423.

the forearm or legs, in which the brachial or femoral may have been tied, does the operation of Anel appear to greater disadvantage. Tying the common trunk for injuries of the smaller vessels of the head or neck is an operation based on a fallacious interpretation of the anatomical and physiological relations of the region. Nothing that is not corroborative of Guthrie's admirable suggestions is found in the preceding cases. If the indolent or timid surgeon, who, to control bleeding from minor branches of the carotid, prefers to stuff the wound with styptics, or to perform the easy operation of tying the common trunk, rather than to seek in the difficult anatomy of the maxillary and thyroid regions to place double ligatures at the bleeding point, he may temporize, or may associate his name with the necrology of ligations; but if his patient recover, it will generally be found to be under circumstances in which the surgeon's operative intervention was uncalled for."

Vertebral Arteries.—An exception to the preceding statements is to be made in the case of wounds of the vertebral arteries. The difficulties which surround the treatment of wounds of these vessels are very great. Fortunately, wounds of these arteries are very rare. Matas,[1] in 1893, was able to collect from literature forty cases of wounds of the vertebral artery, in eighteen of which traumatic aneurisms had formed. Twenty-five of these were the result of punctured or stab wounds, twelve were gunshot wounds, and three resulted from tubercular ulceration. In eight instances only was death averted by treatment. One case, that of Moebus, 1827, is said to have recovered under cold applications! The accuracy of the diagnosis is open to question. In the other cases that recovered the wound was enlarged and direct pressure upon the wounded vessel in the space between the transverse processes was made. In fifteen of the fatal cases the common carotid was ligated on account of failure to appreciate the real source of bleeding. In one case the vertebral artery was tied in the first part of its course (Maisonneuve) with success, so far as control of bleeding was concerned, but with ultimate death from spreading of infection to the spinal meninges. Should enlargement of the superficial wound and retraction of the overlying parts reveal that the vertebral artery has been wounded in that part of its

[1] Annals of Surgery, 1893, xviii., 486.

course between its origin and its entrance into the transverse foramen of the sixth cervical vertebra, an effort should be made to put a ligature around it above and below the aperture in it, temporary closure of the wound being effected by an hæmostatic forceps. If the wound is at a higher point, such ligature is difficult, although under favorable surroundings it might be possible to bite away with a rongeur sufficient of the antero-external portion of the two adjacent transverse processes to permit of sufficient access to the artery to ligate it, as has been proposed by Matas. If it has been possible to satisfactorily place an hæmostatic forceps on the bleeding vessel, it would ordinarily be better to leave it in place for three or four days, at the end of which time, upon its removal, the vessel would remain sealed. If this has been impracticable, systematic plugging of the wound, supported by a bandage so as to maintain constant pressure, may be resorted to.

But in order to secure the success of this operation of plugging the vertebral artery, it is essential that the bleeding point shall be exposed to view, that the plug shall be placed exactly in the open canal of the vessel, which it must completely fill, and that the patient's head shall be held fixed, and the neck immovable, by a stiff collar.

Internal Jugular Vein.—Wounds of this vessel, when treated by exposure of the vessel and the application of a ligature above and below the wound, result happily in a great majority of cases. The free collateral circulation, through the intracranial venous sinuses, the superficial veins of the head and neck, and the sinuses of the spinal canal, prevent serious discomfort from being experienced by the obliteration of so large a channel as the internal jugular vein, when the character of the wound renders such a proceeding necessary. Lateral wounds of this vessel should be closed by the lateral ligature, or forcipressure, if the wound is small; by lateral suture, if the wound is long. The advantages of this procedure are that it may be more quickly done; it demands less extensive dissection and disturbance of the neighboring tissues; it increases the prospects of obtaining union throughout the wound by first intention; and, finally, it preserves intact the function of the vessel.

The chief source of danger which may threaten the success of an attempt to secure lateral closure of a wound of this vein is the normal lateral pressure of the column of blood in the vessel; whenever the head

is elevated, whenever the free entrance of the blood into the thoracic vessels is impeded, as in coughing or straining at stool, this normal pressure is intensified. The contraction of the muscles of deglutition, and of the muscles which cross it lower in the neck—the platysma, the sterno-cleido-mastoid, and the omo-hyoid—may also affect the freedom with which the current through the vein shall pass.

After any wound of the internal jugular vein, and especially in those instances in which a lateral ligature has been applied, the recumbent position must be maintained until firm union of the wound in the vessel has taken place. All movements of the neck must be restrained by the mass and the stiffness of the external dressings applied to the wound. Immobilization and compression, as far as practicable, should be secured.

The material used for all ligatures of the internal jugular vein should be aseptic, and the treatment of the wound should be scrupulously antiseptic, that, if possible, primary union of the wound may be secured.

Lateral ligature of this vessel should be attempted only when aseptic thread, catgut, or silk is obtainable and the subsequent course of the wound can be kept aseptic. In none of the recorded cases has secondary hæmorrhage or other accident disturbed the course of the healing after lateral ligation when these precautions of antisepsis have been observed. The danger of secondary hæmorrhage should deter from resort to lateral ligation of this vessel when ordinary ligatures are used and the wound cannot be kept from septic contamination. When secondary hæmorrhage occurs, it must be treated by exposure of the vessel and the application of a ligature both above and below the bleeding aperture.

WOUNDS OF THE THORACIC DUCT.

The terminal portion of the thoracic duct rises sufficiently high into the neck on the left side to encroach upon the operative field in the case of many growths in that region that are subjected to surgical attack. Numbers of instances in which it has been wounded in the course of such operations have already been published, and in view of the extensive attacks upon carcinomatous and tuberculous glands that are now made as

a matter of common routine, it is probable that the number of unpublished cases much exceeds that of the published ones. The observations of anatomists that in a considerable proportion of cases (25 per cent., Boullard) the thoracic duct empties into the venous system by more than one mouth, and in such instances of multiple stomata always into different vein-trunks, both subclavian and internal jugular, usually, are of surgical importance as possibly lessening the gravity of the accident in a particular case, although in none of the published cases has serious disturbance to nutrition resulted either from the temporary waste of lymph, caused by its continued escape for a time, or by the interruption by ligature or clamp to the current entering the veins; still the known importance of the function of this duct, and the fact that fatal consequences have followed its abrupt occlusion experimentally in animals, must make the possibility of a wound of the terminal portion of the duct a matter of great concern. In its structure and possibilities of repair the thoracic duct resembles a vein, and a wound of it calls for the same treatment applicable to veins. The duct in some cases has been recognized before it was injured as a delicate vessel, filled with a translucent or milky fluid, and has been unavoidably injured on account of its adhesion to the growth being removed; in other cases its vicinity has been known only when the wound has become suddenly filled with lymph from an injury unwittingly inflicted at the bottom of a deep wound. The exact method of treating the wound must depend on the character of the injury. If it is but a prick or a lateral slit, the attempt should be made to control it by suture, applied to its investing connective tissue. Whatever leakage that might still occur could be controlled by gauze pressure until closure of the wound had been effected; in some cases forcipressure would be equally efficient. The object in these manipulations should be to preserve the patency of the duct. If, however, the vessel has been cut across, it should be ligated or clamped, as any vein. The delicacy and pliability of the walls of this lymph duct are such that any ligature applied to the vessel alone would be likely to cut through it, hence it is needful to plan a "mass-ligature" for its secure ligation. In a case in the writer's recent experience the duct was plainly visible, but closely adherent to a carcinomatous nodule situated in the angle at the juncture of the left subclavian and internal jugular veins; in the course of the

manipulations a tear was made in the duct, involving about half its circumference; from this the opalescent lymph flowed freely so as to fill the wound-cavity. A "Péan clamp" was applied laterally; this, though it did not embrace the whole diameter of the duct, practically closed it for the time being. On the third day this was removed; no further escape of lymph took place, and the operation wound healed without disturbance.

WOUNDS OF THE THORAX.

Wounds of the thorax are subject to the same general divisions as those affecting other parts—they may be incised, punctured, or gunshot, contused or lacerated—and are subject to such variations in treatment as may be appropriate to these varieties. More important, however, in this region is the division into non-penetrating and penetrating wounds. The former class includes those wounds which affect the thoracic wall only, without opening the pleural sac. The latter includes all those which involve injury to the contents of the thorax.

NON-PENETRATING WOUNDS.—Superficial wounds of the thorax present no peculiarities requiring special consideration, except the difficulty which attends efforts to secure the advantages of immobility in their treatment, on account of the continual rising and falling of the chest-walls in respiration. As the result, when union by first intention fails to be secured, the healing by granulation is apt to be retarded in its course. This mobility of the thoracic walls may be restricted by surrounding the thorax with a broad, tightly drawn bandage, which will restrain the movements of the ribs, and make the breathing more abdominal in its character.

Deeper wounds of the thoracic wall may involve fracture of the ribs or costal cartilages, and wounds of the internal mammary and intercostal arteries. The methods detailed in Chapter XVIII. should be applied to the treatment of wounds complicated by bone injuries.

Wounds of the arteries should be treated, whenever practicable, by their exposure, and the application of a ligature to both the proximal and distal ends of the vessel. The external wound should be enlarged by in-

cision, if necessary, until the bleeding-point is brought into view. Certain special points in connection with each of these arteries require mention.

Internal Mammary Artery.—The results of wounds of this vessel have been disastrous in most of the recorded cases. Of the five cases in which it was distinctly recognized, and treatment attempted, during the War of the Rebellion, all terminated fatally. When—as is most frequently the case—the wound which has severed this vessel has also penetrated more deeply and has opened the anterior mediastinum, the cavity of the pericardium or of the pleura, the dangers of intra-thoracic and concealed hæmorrhage are added. According to Tourdes,[1] as quoted by the surgical historian of the War of the Rebellion, more than half the cases are accompanied by section of the costal cartilages, and this section always occurs when the vessel is wounded below the fourth rib by an incised wound. There may be external hæmorrhage, and internal, into the anterior mediastinum, into the pleural cavity and into the pericardium. The diagnosis may be very difficult, for the signs of intra-thoracic extravasation are often equivocal. In continuation, Otis quotes the observations of Nélaton,[2] that if the hæmorrhage is suspended at the time of examination, anatomical considerations may afford presumptive evidence, and that every deep wound near the margin of the sternum, from the first to the seventh rib, should be viewed with suspicion. External arterial hæmorrhage decides the point; but this sign is often absent. The diagnosis may be complicated by bleeding from wounded lung, and the internal hæmorrhage then affords no decisive sign, the position of the wound alone suggesting the presumption that the internal mammary artery is interested. The vessel is often of sufficient calibre to furnish blood very freely, and death may result either from the profusion of the bleeding or from asphyxia from hæmothorax. If the blood passes into the pericardium, the heart's movement is impeded and soon arrested; if it enters the pleural cavity or mediastinum, there is room for mortal

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[1] *Des blessures de l'artère mammaire interne sous le point de vue médico-légal*, Paris, 1849, p. 41.

[2] *Elémens de Pathologie chirurgicale*, t. iii., p. 450.

hæmorrhage; and if the patient escape these primary accidents he is exposed to those of putrid decomposition of the extravasated blood.[1]

In all cases, therefore, of deep wounds of that portion of the anterior wall of the thorax, in which the internal mammary artery runs, its external enlargement, sufficiently to permit definite determination of the fact whether this vessel is wounded or not, should be made. The enlargement of the wound should be made by incisions directed slightly obliquely to the axis of the body, from above downward, and from without inward, so that the centre of the incision should be three or four lines external to the margin of the sternum, and in the original wound. All the superficial structures should be freely incised, so as to fully expose the wounded intercostal space. The anatomical difficulties which may embarrass the exposure of the vessel now present themselves. They consist of the shelter which the costal cartilages and the adjacent border of the sternum give to the vessel. In the upper three or four intercostal spaces, sufficient room between the cartilages may be found for the *débridement* needed to expose the vessel; in the lower spaces, resection of a portion of one or more of the cartilages may be needed, and should be promptly and boldly done. The primary and imperative indication is to expose the bleeding vessel, and no superficial structure should be permitted to arrest the effort till its end has been accomplished.

For affording the desired access to the artery, Roberts' "trap-door" temporary resection of the two contiguous costal cartilages[2] is to be commended. A vertical incision is made about 1 cm. laterally to the median line of the sternum, beginning on a level with the top of the costal cartilage which runs above the point of penetration. This is carried through the overlying tissues to the sternum, and is continued downward to the level of the upper border of the third cartilage below; a second incision is made parallel to the first and at from 4 to 5 cm. distance; this is made deep enough to divide all the tissues down to the cartilages; the lower ends of these incisions are joined by a third cut carried along the upper border of the lowest cartilage exposed. The margin

[1] Medical and Surgical History of the War of the Rebellion, Part I., vol. ii., Surgical History, p. 525.

[2] Transactions American Surgical Association, 1897, xv., 117.

of the sternum is now exposed by retracting the soft tissues overlying it, and the two cartilages exposed are divided at their junction with the sternum by a thick-backed, strong scalpel; next these cartilages are similarly cut through along the outer incision, this cut being near the junction of the cartilages with the ribs. Here caution is to be used to avoid puncturing the pleura, which is closely attached to the inner surface of the cartilages in this region. The sections of the cartilages having been effected, the intercostal muscles along the upper border of the intact cartilage exposed by the transverse cut are cut through, and the chondro-muscular-skin flap thus formed is carefully raised from its lower border while the tissues of the mediastinum are gently pushed back from its under surface. There is thus formed a trap-door with a skin-muscle hinge at its upper border. Lying in full view traversing the space exposed will be seen the internal mammary artery and its accompanying veins perfectly accessible for isolation and double ligature. By such a method of approach effusions of blood into the mediastinum or into the pleural cavity may be at the same time evacuated.

The task is more difficult in cases of secondary hæmorrhage, where the adjacent soft tissues have become swollen and infiltrated, and the vessel lacerated and displaced. The attempt to secure it in the wound, however, should be made; failing in that, the tampon might be resorted to, after the plan of Desault. This consists in placing over the wound a fine compress, four or five inches square. The centre of this is pressed through the wound so as to form a glove-finger-like sac projecting into the thoracic cavity. This is then stuffed firmly with lint; the angles of the compress on the outside are then brought together, and the intra-thoracic pad or ball of lint is drawn gently outward, and made to compress the wounded vessel against the sternum or ribs. To keep the pad in place, the compress may be tied like a purse, and the ligature secured around a roller or other convenient cylinder. According to Otis, this is the best resource, if the attempt to ligate the vessel fails. The hazard of exciting inflammation in the pleura and lung is less to be dreaded than the danger of hæmothorax. The risks of exciting inflammation of the intra-thoracic parts would be lessened by using antiseptic materials, such as iodoform gauze, in making this tampon.

Intercostal Artery.—In recent wounds, properly directed attempts to

be made, after which the general cares demanded by penetrating chest-wounds, as a whole, will be considered.

Heart and Pericardium.—Not every wound of the heart results fatally. The statistics of Fisher,[1] for which we are indebted to quotation by Otis (op. citat., p. 530), state that out of 452 cases analyzed, 75—16.3 per cent.—recovered. Many instances are recorded of death occurring some hours or days after the reception of a wound of the heart by a gradual leakage from it, the blood escaping into the pericardium, and also, in some cases, into the pleural cavity through a pericardial wound, and producing death either by the loss of blood, or by the embarrassment to the heart occasioned by the accumulating effusion in its investing sac. If such cases could be recognized before death, with any degree of certainty, their otherwise hopeless course would justify an exsection of the overlying cartilages, an incision into the pericardium, the evacuation of the effused blood, and an attempt to suture the rent in the heart-wall. That the pericardial cavity can be opened for a short time with impunity in the human being, Koenig's case of excision of the sternum,[2] in the course of which both pleural cavities and the pericardium were opened into, has demonstrated. In this case the openings were at once occluded with antiseptic gauze. The dressing was not disturbed for twelve days. Ultimate recovery was secured. Block[3] has farther shown that in dogs, not only can the pericardial cavity be opened with impunity, but the heart may be seized at its apex, and held still sufficiently long for the introduction of a suture, and still have it resume its pulsations. It is not impossible that heart-suture may yet be successfully performed in the human subject.

This hope, expressed in 1882, has since been realized in fact. At the 1897 meeting of the German Congress of Surgeons, Rehn, of Frankfort, reported the case of a man, 22 years of age, who was admitted into his hospital on the 7th of September, 1896, in collapse, with a wound 1.5 cm. long, in the fourth left intercostal space, which was not bleeding ex-

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[1] *Die Wunden des Herzens und des Herzbeutels. Archiv für klinische Chirurgie*, ix., 571.

[2] *Allgemeine Wiener medicinische Zeitung*, September 25, 1882.

[3] *Gazette Médicale de Strasbourg*, October 18, 1882.

ternally. While under observation there was an increase of dyspnœa and of dullness throughout the left thorax, with respirations 76 per minute.

A portion of the fifth left rib near the mammary line was resected, evacuating a large amount of blood from the pleural cavity, after which a small opening was discovered in the pericardium from which venous blood was flowing. The pericardium was then freely incised and lifted up by clamps applied to its wound edges, by which means the heart was brought up into full view, and a wound 1.5 cm. long revealed in the middle of the right ventricle, from which blood was flowing freely. This wound was then closed by three interrupted silk sutures, stopping the bleeding at once.

The action of the heart could be seen perfectly during these procedures. It was observed that the finger could be pressed upon the wound in the heart sufficiently to stop the bleeding without interfering to any considerable extent with the action of the heart, but the introduction of the needle and the drawing up of the suture caused each time a momentary stopping of the heart's action. Although the later progress of this case was complicated by pneumothorax and long-continued suppuration, a complete recovery was eventually secured.

A floating paragraph in recent medical journals attributes another case of successful heart-suture to Parozzani, of Rome. I have not been able to verify the reference, but as the method stated to have been pursued is one to be recommended in similar cases I quote the account:

"A man, in a state of collapse, was brought to the hospital five hours after having been stabbed in the left side. The thorax was at once opened by the raising of a flap containing portions of the fifth, sixth, seventh and eighth ribs, the flap being left attached at its sternal border. The left pleural sac was found to be filled with blood, and an opening in the pericardium an inch in length was visible. A finger passed into this opening felt a jet of blood issuing from a wound in the left ventricle at each heart-beat. The pericardium having been opened freely, the wound in the heart was closed by four stitches; then the pericardial wound was sutured, and finally the skin incision. The patient recovered completely."

Lungs.—The wounded lung will collapse more or less closely, according to the size of the aperture in the thoracic wall, and the freedom with

which air can pass into the cavity of the chest through it. In rare instances protrusion of a portion of the lung through the external wound has taken place. The lung-wound may bleed, may become inflamed, may be complicated by the retention within it of a foreign body. The bleeding from a lung-wound will exhibit itself both by a bloody expectoration, and by effusion into the pleural cavity. Its arrest must be procured by general measures; absolute quiet and silence; ice, swallowed, and also applied to the surface of the chest; ergotine, hypodermically administered; opium; heat and counter-irritants to the extremities. The management of accumulations of blood in the pleural cavity will be considered in another connection. Traumatic pneumonia does not involve large portions of the lung structure, as in the idiopathic variety, but is limited to the vicinity of the wound track. The inflammatory exudation may be absorbed, may be discharged through the bronchial tubes, or may accumulate in the cavity of the pleura. From the latter cavity they will need to be evacuated by incision and drainage.

Foreign bodies embedded in the substance of the lung are not to be searched for, but left to their spontaneous course. Should the patient survive, and continued ill effects be experienced from the foreign body, the propriety of exploratory operation, and of resection of a portion of the lung may yet become a matter of consideration. The experiments of Block,[1] upon animals, in which recovery and survival, in apparently good health, was secured after the removal of from one to four pulmonary lobes, are sufficiently encouraging to suggest the hope that such an operation may be proven to be available for the relief of otherwise hopeless cases of prolonged suppuration and irritation from the retention in a lung of a foreign body.

Hernia of the lung should be treated by carefully cleansing and disinfecting the protrusion, and, if possible, returning it into the thoracic cavity, enlarging as much as may seem prudent the original wound, in order to favor the return. If reasonable attempts to reduce fail, either ligation and excision may be done, or no interference be attempted beyond protecting the protrusion during the course of its becoming adher-

[1] *Experimentelles zur Lungenresection. Deutsche med. Wochenschrift*, Berlin. 1881, vii., 634-636.

ent to the margins of the wound and its ultimate cicatrization. In most of the recorded cases the former has been done, and without bad results. The material for the ligature should be aseptic, and the stump, after having been disinfected, may be returned to the pleural cavity without hesitation.

Pleuræ.—By the penetration of the pleural sac, air and blood enter its cavity; air escaping again through its external opening may become diffused among the interstices of the subcutaneous connective-tissue; and, finally, septic inflammation of the pleural membrane itself, with accumulation of inflammatory products in its cavity, may follow.

In general the mere fact of the presence of air and blood in the pleural cavity does not call for active interference unless they accumulate in such quantity as to embarrass the action of the sound lung. The escape of blood to such an amount would be fatal from the loss of blood alone.

Hæmothorax.—Signs of an increasing accumulation of blood in the pleural cavity call for a renewed examination of the wound in the parietes, to exclude a possible hæmorrhage from a superficial vessel. If such should be found, it should be secured by ligature at once. If not, the opening into the thorax should be made sufficiently free, so that the blood being effused into its cavity may escape externally, while the general measures for arresting the hæmorrhage, which have been referred to in connection with bleeding from the lungs, should be adopted. Effusions of blood which have been retained in the pleural cavity and have undergone decomposition are to be removed by incisions through the wall of the chest, and by antiseptic irrigation.

Pneumothorax.—The relief of troublesome pneumothorax is to be accomplished by dilating the external wound so that the escape of air from the wounded cavity may meet with no obstruction.

Emphysema, rare after gunshot wounds, and more frequent after oblique stab wounds, is due to a want of parallelism between the superficial and the deep portions of the parietal wound. The wound should be enlarged sufficiently to make the whole track free and direct. The swollen tissues should be compressed by a bandage; punctures and scarifications may be made if needed, but will rarely be required.

Empyæma and *Hydrothorax.*—Accumulations of fluid, the results of traumatic pleurisy, require thoracentesis for their removal. Simple se-

rous exudation may be removed by aspiration; sero-purulent and sanguineo-purulent collections should be evacuated by free incision of the thoracic wall, and drainage until obliteration of the purulent cavity is accomplished. Exsection of a portion of a rib may be done, if necessary to give the required freedom to the opening. The opening should be free enough to admit a finger easily, and to permit the escape of any fibrinous shreds, masses of gangrenous tissue, or foreign bodies that may be loose in the pleural cavity. In resecting a rib, the method of procedure should be as follows: Make an incision for two inches or more directly over the rib selected. This should be deepened until the rib has been completely exposed throughout the length of the incision, and then the periosteum divided in a direction parallel to the long axis of the bone. Then raise it by means of a periosteum-elevator, which is also passed beneath the rib so as to separate it from the deep surface, a manœuvre which is rapidly and easily accomplished. A curved elevator is then slipped completely beneath the rib, which is thus raised slightly from those immediately above and below it, and a piece, from one to two inches long, is cut out by suitable bone-cutting forceps. This is all completed before the pleura, or indeed the deep part of the periosteum, is in any way interfered with. The soft parts being held aside with hooks, the pleura is then incised at leisure, and the opening is enlarged by expanding the blades of a pair of dressing forceps. The risk of wounding the intercostal artery is thus absolutely avoided, and if any vessel be divided, either in the superficial or the deeper structures, it is easily seen and readily secured. Such an opening will admit the finger, if it be thought advisable to introduce it, and in the subsequent progress of the case the removal of the portion of the rib leads to no inconvenience.

Patency of the wound through the chest-wall is the chief point upon which subsequent uncomplicated progress of the case will depend. It is not necessary to use drains that reach the bottom of the pleural cavity; they need merely be long enough to protrude fairly into that cavity; an average length of two inches is sufficient. Two such tubes, of a quarter inch lumen, should generally be inserted. A safety-pin should be thrust across the out end of such a tube to prevent possibility of the tube accidentally slipping into the pleural cavity, an accident which has happened many times. If retention of effusions occurs at a distant point,

a counter opening at the point in question, with independent drainage, should be made.

The final dressing of the wound should be made by a copious mass of absorbent gauze, or other sterile material, secured in place by a broad bandage encircling the thorax. Changes of dressing should be made as rarely as possible, the guide being the saturation of the dressings with discharges or the symptoms of retention of infected secretions.

CHAPTER XXI.

WOUNDS OF THE ABDOMEN—OF THE PELVIS.

Non-penetrating Wounds of Parietes*—Arrest of Hæmorrhage—Apposition—*Penetrating Wounds without Injury to Viscera*—The Peritoneal Wound—The Peritoneal Suture—Closure of Wounds of the Abdominal Walls—Protrusion of Viscera—Intestine—Omentum—Other Viscera—*Penetrating Wounds with Injury to Viscera*—Exploration of Abdomen—Diagnosis Positive—Diagnosis Presumptive—Arrest of Intraperitoneal Hæmorrhage—Primary Cleansing of Peritoneal Cavity—Drainage—Peritonitis and Septicæmia—Suture of Intestinal Wounds—The Lembert Suture—Preliminary Coprostasis—The Czerny Suture—The Continuous Intestinal Suture—Emmert's Suture—Halsted's Suture—Cushing's Suture—Testing the Suture—Omental Grafting—Preservation of Calibre of Intestine—Prevention of Necrosis—*Circular Enterorrhaphy*—Preliminary Stitches—Permanent Sutures—The Mesenteric Stitch—The Method of Maunsell—Circular Suture with Mechanical Aids—Vegetable Cylinders—Rubber Bags—The Murphy Button—*Wounds of the Kidneys—Wound of a Ureter—Wounds of the Urinary Bladder*—Extraperitoneal Rupture—Intraperitoneal Wounds—Laparotomy—Suture of the Bladder—Continuous Catheterization—*Wounds of Anus and Rectum.

WOUNDS of the abdomen may involve simply the abdominal wall, without penetration of the peritoneal sac; they may penetrate the peritoneal sac without wounding any abdominal viscera; they may involve wounds of any of the viscera. Each class presents certain features in treatment which require special consideration.

NON-PENETRATING WOUNDS OF THE PARIETES.

ARREST OF HÆMORRHAGE.—When arterial bleeding is present, the general rule, that the bleeding vessel shall be exposed in the wound, and a proximal and distal ligature be applied to the divided ends, is imperative. The internal epigastric, the internal mammary, and the internal circumflex iliac arteries, when wounded, may retract within the muscles among which they lie, and cause trouble in securing them; should at-

tempts be made by compression and styptics to control the bleeding, extensive interstitial extravasation would be endangered, entailing suppuration and sloughing, even though the hæmorrhage be primarily checked. Punctured wounds of these vessels are liable to the same danger of hidden extravasation. In cases of penetrating wounds, the blood may flow into the peritoneal cavity and be concealed. In case of a deep wound of the abdominal parietes, involving the muscles, the surgeon should be sure that perfect and definite hæmostasis has been secured before the wound be closed. Every arterial branch that bleeds should be tied, and double ligature of the larger trunks must not be neglected.

Should extravasation of blood among the intermuscular or interaponeurotic spaces have already taken place, the clots should be removed as far as possible, and thorough disinfection of the parts be made. Should the case have proceeded to the point of clot-decomposition and suppuration, free incisions, antiseptic irrigations, and drainage should at once be made.

Apposition.—Wounds in the abdominal parietes require that careful apposition of all the divided structures should be secured, to prevent premature weakening of its structure. The points connected with suture of wounds of the abdominal wall in general are considered in detail in connection with the penetrating wounds.

PENETRATING WOUNDS OF ABDOMINAL WALL WITHOUT INJURY OF VISCERA.

Wounds which pentrate the peritoneal cavity, without injuring any contained viscus, may not differ from non-penetrating wounds, except in the addition of the wound in the peritoneum; they may be complicated by protrusion through the wound of some of the abdominal contents; they may be complicated by the entrance of foreign matter or blood into the peritoneal cavity.

The Peritoneal Wound.—Any wound in the peritoneum more extensive than can be controlled by a single point of suture is best secured by a special line of continuous catgut suture, the suture taking in only the peritoneum and subserous connective tissue. This insures with cer-

tainty the accurate closure of the peritoneal rent throughout its whole extent. Gaps in the peritoneum are to be prevented with care, for otherwise the raw surfaces left exposed inevitably form dense adhesions with the subjacent parts, and subject the patient to possibilities of subsequent trouble from bowel angulation or band-obstruction. The adhesion of the peritoneal margins is very rapidly established, the reparative processes in the serous membrane of the abdomen being identical with those described for the intima of blood-vessels (page 302). The suture should be applied so as to appose peritoneum to peritoneum, the exact opposite of the conditions required for the union of skin or mucous membrane, union of wounds in which is prevented by inversion of the skin or membrane into the wound. When the peritoneal margins of a wound are brought and held in apposition by sutures, throughout the area of traumatic congestion adjacent to the wound edge, or the needle puncture, lymph is effused, which fills up the angle of union, becomes organized, and repairs the defect so perfectly as to render indistinguishable the line of union. This rapid and solid plastic exudate early forms a reliable barrier against infection from without, so that in case of suppuration developing in the more superficial part of the wound it rarely involves the peritoneum, however widely it may diffuse itself among the superficial tissues of the abdominal wall. When, however, the emergencies of a particular case are such as to call for extreme haste in getting an abdominal wound closed, or where by reason of loss of much substance the tension upon the comparatively delicate peritoneal tissue is so great as to tear it, the special peritoneal line of suturing must be omitted, and the peritoneum closed by being included in the single strong suture which takes in the whole thickness of the abdominal wall. Such sutures should be inserted externally about half an inch from the border of the skin-wound, should be made to sweep outward so as to include a thicker mass of tissue in the middle of the bight, and then should slope toward the inner surface so as to perforate the peritoneum not more than a quarter of an inch from the wound margin. The crossed suture (page 209) is of especial value in securing exact coaptation of the different layers of a wound in the abdominal parietes. In the case of a thick abdominal wall, some form of quill or pad suture should be combined with the crossed suture (Figures 75 and 81). The firm re-

union of each layer of tissue presented in a wound of the abdominal wall is of primary importance so as to reduce the cicatrix to its least possible degree, for the cellulo-fibrous tissue of such a cicatrix, when it reaches the stage of atrophy, is extensible and frequently leads to the development of ventral hernia. In the deliberate operative wounds made by a surgeon, whenever it is possible to avoid cutting across muscular fibre, the muscular fasciculi should rather be separated, and whenever it is possible to plan an incision so as to carry it through a layer of separated muscular fasciculi it should be done. From the standpoint of the final firmness of the cicatrix, wounds along the course of the linea alba are therefore to be deprecated; in most cases an incision carried so as to go through a rectus muscle affords equally good access to the peritoneal cavity. The ideal method of closure of a wound in the abdominal wall is by catgut suture of the peritoneum, buried chromic gut suture of the deep musculo-aponeurotic layer, buried catgut suture of the aponeurosis of the external oblique and deep layer of superficial fascia, and subcuticular silk suture of the remaining superficial wound. See Figure 82, page 210.

PROTRUSION OF VISCERA.—The viscera most frequently met with protruding through wounds of the abdominal parietes are the small intestine and the omentum. Instances of protrusion of the stomach, liver, spleen, kidneys, and bladder have been noted. Many instances of recovery from the most extensive and aggravated wounds of this character, under very unpromising circumstances, are on record, so that no case of the kind should be despaired of. The following recent cases may be quoted in illustration of the truth of this statement:

1. Case reported by Simpson,[1] of Michigan. Male, 30 years of age, cut his abdomen open with a razor, while in the woods. Seen by the surgeon four hours after the occurrence. Was then covered by an old bed-quilt, which was adherent to the protruding intestines. Wound was in middle line, eight inches in length, extending from the ensiform cartilage to a point below the umbilicus. Through this a mass of intestines, consisting of eight inches of transverse colon and twelve feet of small intestine and omentum protruded; the intestines were dry and

[1] Medical Gazette, New York, 1882, p. 225.

wrinkled, covered with cinders, dust, sand, and a variety of foreign matter which had been rubbed in as the man had rolled over and over on the ground in his agony. Under chloroform, the larger bits of foreign matter were picked off, and the intestines washed in water from a neighboring brook, and the protruding viscera returned. A quantity of blood effused into the peritoneal cavity was mopped out with a handkerchief. The wound was closed by a continuous suture applied so as to include the whole thickness of the wound-edges. Difficulty was experienced in preventing the omentum from protruding while the suture was being applied, and in the lower half of the wound it became adherent to and united with the lips of the wound. The man was then removed in a lumber wagon four miles to a town, and placed on a dirty cot-bed in the city fire-engine house. Rapid recovery without an untoward symptom took place, so that he was discharged from treatment on the fifteenth day after the occurrence.

2. The second case[1] is very similar to the first. A male, 55 years of age, attempted suicide, and cut his abdomen with a large knife four successive times. When first seen, three hours after the accident, the patient was found lying on the dirty floor of a cattle-hut, in a fainting state, with all the small intestines and the whole omentum majus protruding out of a clean-cut wound which extended from the scrobiculus cordis far below the umbilicus. There were seen also three other smaller wounds, all of them perforating the abdominal wall. The protruded parts, which were covered with mud and blood, were washed with tepid water and returned, and then all the wounds closed with silk sutures, and dressed with cold water. Three weeks later the patient left the hospital, having recovered without any complication except a small abscess in the abdominal wall near the largest wound.

3. Case reported by Harte,[2] of Philadelphia. A man, 40 years of age, deliberately thrust a knife into his abdomen on the left side, and drew it across to a corresponding point on the opposite side, making a transverse wound from eight to nine inches in length just above the umbilicus. He was immediately seized and transported to the Pennsyl-

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[1] Sarmatsky, *Vrachebniya Vaidomosti*, St. Petersburg, 1882, No. 16.

[2] Annals of Surgery, 1898, xxvii., 748.

vania Hospital, upon his arrival at which place it was found that the transverse colon, omentum, and a large mass of intestines were protruding from the wound, and that a loop of small intestine, about fifteen inches in length, had been severed from its mesenteric attachment, while the entire protruding mass had become soiled from contact with clothing and dust from the bottom of the wagon in which the patient had been conveyed. Active bleeding was going on within the abdominal cavity. The wound was further enlarged by a median incision to enable the surgeon to expose the bleeding mesenteric vessels and to ligate them. The intestinal mass was then thoroughly cleansed with hot distilled water and replaced within the abdomen, except that part which had been severed from its mesenteric attachment. About eighteen inches of this injured bowel were resected, the cut being made through uninjured tissue on either side. End-to-end anastomosis of the cut bowel with a Murphy button was made. After a final thorough douching and washing out of the abdomen with hot water, the abdominal wound was sutured, with a glass drain at the lower angle of the vertical incision. The patient recovered, the healing of the wound being complicated only by a limited superficial suppuration.

Out of 307 cases of penetrating incised wounds of the abdominal cavity reported by Albanese,[1] of Palermo, in only six instances did death result from simple diffuse peritonitis. In these cases, protruding intestinal loops were always carefully washed with carbolated water, and any wounds in the intestines sutured before the protrusion was returned.

In general, the rule of treatment in this class of cases is to cleanse and disinfect the protruding viscus as carefully as possible, and return it into the abdominal cavity, after which the wound should be treated as one without protrusion. Attention must be directed, however, to modifications of this rule demanded in certain circumstances.

Intestine.—So large an amount of intestine may have escaped through the wound that it can no longer be passed back through the opening by which it escaped. In such a case the wound must be enlarged until the return of the protruding intestine is possible; care

[1] Transactions of the International Medical Congress, London, 1881, ii., 437.

should be taken to make the incisions at those portions of the wound which resist distention and act as agents of constriction. The return of the intestine should be followed by insertion of the finger to determine with certainty that the gut has been replaced in its proper cavity, and not crowded between the peritoneum and the superficial tissues.

The difficulty in reduction may depend on the distention of the bowel by flatus. If so, an attempt to press it back into the portion of intestine within the abdomen should be made. If this is unsuccessful, and the protrusion is great, with excessive distention, the bowel should be punctured with an aspirating needle through which the gas may escape. In such case the point of puncture should be guarded by a point of suture inserted before replacing the intestine.

The intestine may have been strangulated by the constriction of the wound through which it has been forced. If, after the constriction has been relieved, the circulation in the previously strangulated loops resumes its natural course, reduction of the gut, and closure of the wound should be made. If gangrene is already present, or if the feeble and imperfect return of the circulation, after dividing the stricture, indicate that it is inevitable, the bowel should be left in the wound, to the margins of which it will have contracted adhesions, an incision should be made into the bowel and an artificial anus created. If the general condition of the patient is such as to warrant any prolongation of manipulation, the gangrenous or dying portion of the intestine may be at once excised, followed by enterorrhaphy.

Omentum.—Protruding omentum, which cannot be readily replaced, should be ligated at its base and cut off; if an aseptic ligature has been employed, the stump may be dropped back into the abdomen, and the abdominal wound may be closed; if an ordinary ligature be used, the omentum must be left in the wound, and healing by granulation awaited. Protruding omentum that is very dirty, that is congested in any degree, or into whose substance extravasations of blood have taken place, should be excised. If the size of the omental mass, that is to be excised, be considerable, its base should be ligated in two or more parts.

Protrusion of other Viscera.—Protrusions of the stomach are to be treated in accordance with the rules for the intestines.

In cases of protrusion of the bladder, evacuation of the urine should

first be secured by the introduction of a catheter, after which its reposition may be effected without difficulty.

Protrusions of portions of the spleen, or of the liver, have occurred. The general treatment of such protrusions should be the same as that given for protruding omentum.

Cases of complete protrusion of a kidney through a wound are recorded in literature as rare occurrences. Tuffier[1] has collected seven such cases. In two of these the kidney was removed, in one being cut away after ligation of its pedicle, in the other by the gradual cutting of the pedicle by a tight ligature.

PENETRATING WOUNDS OF THE ABDOMINAL WALL WITH INJURY OF VISCERA.

In the treatment of this class of wounds, the surgeon will need to specially consider the subjects of exploration of the abdominal cavity, arrest of intraperitoneal hæmorrhage, suture of visceral wounds, primary cleansing of the peritoneal cavity, secondary cleasing or drainage, and secondary septic complications.

Explorations of the Abdominal Cavity.—The evidences that an abdominal viscus has been wounded may be either positive or presumptive. The escape through the opening in the parietes of the contents of the alimentary tube, of the bile or of the urine, or the protrusion externally of the wounded viscus, so that the wound is subject to actual inspection, alone can be considered as positive proof of visceral injury. When any of these conditions are present, the duty of the surgeon is, clearly, to enlarge the opening in the abdominal wall, or to make a new one in a more favorable location, sufficiently to admit of examination of the viscera in the track of the wound, to expose and ligate bleeding vessels, to suture intestinal rents, and to thoroughly cleanse the peritoneal cavity of extravasated matters.

In the great majority of cases of visceral wound, however, positive evidence is wanting, and simply a more or less strong presumption of the fact of the wound exists. In these cases it should first be established,

[1] Archiv. gen. de Méd., 1889.

by superficial exploration, that penetration of the peritoneal cavity has taken place. In this respect an exception should be made to the general rule given in the case of gunshot wounds to abstain from all primary exploration of their track. Gunshot wounds of the abdominal walls should be explored in all cases, as soon as the necessary requisites of aseptic cleanliness can be complied with, sufficiently to determine whether they do or do not penetrate the peritoneal cavity.

The fact of penetration having been established, the further course to be pursued becomes a matter of grave consideration, whenever signs of already impending dissolution do not absolve the surgeon from all responsibility. With but few exceptions, this class of wounds are gunshot wounds. A policy of non-interference, and of expectant treatment by rest, cold, and opiates, was pursued in the treatment of these cases until within quite recent years. Up to 1885 only six instances of abdominal section for their relief were recorded (Parkes). Under this treatment, 87.72 per cent. of all penetrating gunshot wounds of the abdomen, during the War of the Rebellion, terminated in death. During the Crimean war, 91.7 per cent. of the cases among the French, and 92.5 per cent. among the English, died. Of the cases that recover, the larger proportion are among those in which the protrusion of the viscera, or the adhesion of the margins of the internal visceral wound to the margins of the external wound so that the contents of the viscus escape externally, relieve the surgeon from all doubt as to the course he should pursue. Of the few cases that remain, in some the recovery has taken place though positive evidence of visceral penetration has been given by the subsequent voiding of the bullet *per anum,* and in yet others in which the symptoms have afforded strong presumptive evidence of visceral wound, as in the following case, reported by Schapps:[1] a male, aged twenty years, was admitted into St. Vincent's Hospital, New York, in the service of Dr. Charles Phelps, May 26, 1880, having been shot by a pistol at a distance of three feet. The bullet penetrated the abdominal wall two and a half inches above and to the left of the umbilicus. General condition when admitted fair, but within half an hour experienced great depression of vital powers, and vomited considerable blood. Ice,

[1] Annals of Anatomy and Surgery, 1881, iv., p. 88.

stimulants, and opium were given. He was discharged on the twenty-second day thereafter, cured.

It should also be remarked that instances have been recorded in which the abdominal cavity has been transversed by a bullet, or transfixed by a weapon, without injury to any of its viscera.

In any individual case, the possibility that it may prove to be one of the rare exceptions to the general rule of fatality, will have its influence on the decision of the surgeon as to the course which he shall pursue.

The cause of death in the fatal cases is either shock, hæmorrhage, or septic peritonitis. Death from the first two causes is speedy, so that, except in rare instances of slowly accumulating blood-extravasations, they do not require special consideration here. The latter cause of death, septic peritonitis, is more slow in its operation, and hence engages the more particular solicitude of the surgeon as to the later effects of the treatment that he may give. Most important of all would be its prevention, but in these injuries the cause is inherent in the wound itself, from the extravasation of the septic contents of the wounded organs into the peritoneal cavity. Free incision, exploration, disinfection, and drainage constitute the treatment for similar conditions in other regions of the body, and would be resorted to in all cases of penetrating wounds of the abdominal cavity were it not for the special dangers which such practice involves. These are the shock of the exposure and the handling of the abdominal contents, the danger of awakening fatal inflammation by the operation itself, and the possibility of disturbing repair which if left alone would have accomplished recovery, and finally, the possibility of overlooking wounds from which subsequent extravasations would occur.

In forming his final conclusion as to the course which he should pursue in the treatment of those cases in which presumptive evidence only exists as to the occurrence of visceral injury, these dangers attending the exploration and cleansing of the abdominal cavity, are the only conditions that can weigh for much. They were until recently sufficient to deter all surgeons from its practice. The great proportion of recoveries, however, which followed the free abdominal incisions, and the prolonged manipulations, and the often great traumatism, inflicted upon the abdominal viscera, in the operation of ovariotomy, as performed by

many surgeons, first demonstrated that less danger attended mere traumatic injuries of the peritoneum than had been supposed; the dangers of septic infection and their methods of avoidance became more clearly defined by increasing experience in all classes of intraperitoneal work, while new experimental knowledge as to the power of resistance to infection possessed by the peritoneum and the capacity to overcome it gave greater confidence in attempting to relieve surgical conditions within it. In view of this more accurate knowledge now possessed as to the management of peritoneal wounds, the laying open the abdominal cavity and the exploration of its recesses in all cases of perforating wounds, with possible visceral injury, has become accepted as justifiable and imperative. The danger that by such procedure adhesions would be broken up, which if let alone would have accomplished spontaneous recovery, is too infinitesimal to be permitted to have any weight; while the final danger that possibly some wound might fail to be detected and secured, as the result of which all that had been done would be useless, should stimulate rather to increased thoroughness in the exploration than to refusal to attempt it at all.

In any exploration of the peritoneal cavity, the surgeon must observe every precaution lest he himself, in his manipulations, introduce septic matter. Every precaution of asepsis should be rigidly observed in the persons of the surgeon and of his assistants, and in his sponges, instruments, and appliances. The external surface of the abdomen must be carefully cleansed and disinfected, and the subsequent dressings should be antiseptic in character.

Arrest of Intraperitoneal Hæmorrhage.—Whenever evidences of intraperitoneal hæmorrhage are present, there is but one resource, the enlargement of the external wound, or the making of an incision through the abdominal wall in a more suitable situation, and the exposure and ligation of the bleeding vessel. Aseptic silk or catgut should be used; the ligature should be cut short and left in the peritoneal cavity.

Parenchymatous hæmorrhage from the tissue of a wounded liver, spleen or kidney can be arrested by the insertion of one or more points of suture, so placed that when tied the bleeding surfaces are held together with gentle pressure. Owing to the friability of the tissue of these organs, it is necessary to insert the suture at some distance from

the wound edges and carry it in deeply, lest it tear out when tied. But little pressure is required to control bleeding in them. A large sized catgut thread and a needle without any cutting edges should be used. A tampon of iodoform gauze may be substituted for the suture in cases of considerable laceration of tissue, or in wounds that are not easily accessible for suturing. An oozing from a superficial abrasion may be checked by the actual cautery.

PRIMARY CLEANSING OF THE PERITONEAL CAVITY.—In all wounds attended with extravasation into the peritoneal cavity of matter, either septic or prone to become septic, the most thorough and scrupulous cleansing of the cavity must be practised. The external wound must be enlarged, if necessary, sufficiently to admit of the complete performance of this duty. After all hæmorrhage has been absolutely and definitely arrested, and suture of the visceral wounds has been accomplished, all foreign matter, blood and serum must be removed. For this purpose irrigations and spongings may be used. The irrigating fluid should have been boiled, and should still have a temperature of from 100° to 110° F. It should be made to approximate the specific gravity of the serum of the blood, by the solution in it of a small quantity of common salt. The nozzle of the irrigating tube should be introduced deeply into the peritoneal recesses both of the abdomen and of the pelvis. In many cases the coils of intestine may be held aside, or the intestinal mass has been eventrated so that the recesses of the abdomen are more fully exposed and a stream of fluid can be poured into them from a pitcher or bottle. While the irrigation is being practised, the position of the patient can be changed so as to facilitate the free escape of the irrigating fluid. Sponging should be done by soft and pure sponges, secured to a sponge-holder or grasped in a forceps, by which they are carried down to the farthest recesses of the peritoneum. No loose sponge should be thrust into the abdominal cavity, on account of the danger of its being overlaid by the intestinal folds and left in the cavity. The sponging should be continued until the peritoneum is clean. Removal of intraperitoneal effusions must in all cases be made as perfectly as possible, with the best means at the command of the surgeon. It is not necessary to finally sponge out all the saline fluid with which the cavity may have been flooded; if care has previously been taken to thoroughly flush

out septic material, considerable of the saline solution may be left in the cavity, with the effect of lessening shock and promoting convalescence.

DRAINAGE.—The conditions which the peritoneal cavity presents are such as to modify somewhat the relations of artificial drainage in the case of wounds within it. The large size of the cavity prevents the occurrence of tension within it, though copious secretion has taken place. The absorptive powers of the serous lining suffice, in many cases, to rapidly remove effusions, and thus to prevent their accumulation and putrefaction. The natural great vital resisting power of the peritoneum enables it, under normal conditions, to overcome the invasion of large numbers of pyogenic organisms. On the other hand, the track of a drain is with difficulty prevented from becoming itself infected, and may lead to a spreading infection of the peritoneum. It is also a serious consideration to be taken into account that the site of the drain remains as a weak spot in the ventral wall, predisposing to subsequent hernia. The healing of the drain track necessarily prolongs the convalescence. Drainage, therefore, should be resorted to only when there is a clear indication for its use, and those surgeons who are the most certain masters of the art of "preventing infection" (Chapter VI.), and who give the most attention to the removal of blood-clots, the covering in of denuded surfaces with peritoneum, and the avoidance of pockets in which secretions may be retained, will find that these indications become very much restricted, and that they are able to dispense with drainage in most cases of intra-abdominal wounds.

When, however, for the control of hæmorrhage a tampon has been required, the question of drainage is at once settled in that particular case when the end of the tampon-gauze is brought out through the parietal wound; in dealing with intraperitoneal conditions in which sepsis is already present, drainage is to be unhesitatingly used; in dealing with wounds as the result of which the contents of any portion of the alimentary canal have been extravasated, however careful the attempts at cleansing may be, the suspicion of uncontrollable infection is so great that as a preventive appliance an abundant drain should be inserted. In the case of wounds of the bladder, or of the ureter, to the secure suturing of which absolute certainty can not attach, a temporary drain is indicated.

The primary drain should be composed of folds of gauze; if the case is a septic one, these should be iodoformized, or if a large quantity of gauze is required to drain a large area, layers of simple sterilized gauze should be enfolded in the iodoformized strips. These drains should reach the surface of the abdomen by the shortest route possible, and counter-openings for this purpose should be unhesitatingly made wherever required. The subhepatic fossa, the posterior cæcal fossa, the left lumbar fossa, and the cul-de-sac of Douglas are the regions most frequently requiring counter-openings for their adequate drainage. The incision through which the drain is brought must be left sufficiently freely open so that the drain shall not be constricted and the free outflow of the fluid conducted by it prevented. The projecting ends of the drain should be covered by an abundant layer of moist sterile gauze, and this should be changed as often as it is saturated by the discharges. All manipulations of these dressings should be guarded with as scrupulous care to avoid infection as in the making of an original operative wound. If no symptoms of retention develop, the primary drain may be left undisturbed until the fourth day, when it is easily removed, and with very little pain to the patient. In many cases the drain track quickly collapses, and the superficial wound requires the simplest subsequent attention; if the need is felt of longer control of the conditions at the bottom of the drain track, a single strand of gauze may be inserted. At the end of another forty-eight hours, if but a scanty serous secretion appears, the drain is removed altogether, and the parietal wound either closed by suture or left to granulate. If a purulent secretion from the drain track appears, a moderate-sized soft rubber tube is inserted, and the further care of the sinus is conducted on the same lines as are adopted for similar conditions in other parts of the body.

Peritonitis and Septicæmia.—The so-called traumatic peritonitis is in all cases a septic inflammation, and kills quickly by the rapid absorption of the abundant septic products—ptomäines—which are drank up rapidly by the serous membrane as they are generated in the copious inflammatory secretions. The one imperative thing to be accomplished by way of treatment is to secure the immediate removal of the poisonous exudations. This may require a reopening of the abdomen, repetition of the irrigations, and more effective provisions for drainage. The

presence of diffuse peritonitis is not a counter-indication to such opening and cleansing, but, on the other hand, is a condition that directly calls for it.

SUTURE OF INTESTINAL WOUNDS — ENTERORRAPHY.— In suturing intraperitoneal wounds of the alimentary canal, the apposition of the serous surfaces adjacent to the wound edges, rather than of the wound edges themselves, is of the greatest importance. Primary union of the cut edges of the intestinal wall is prevented both by the thinness of the

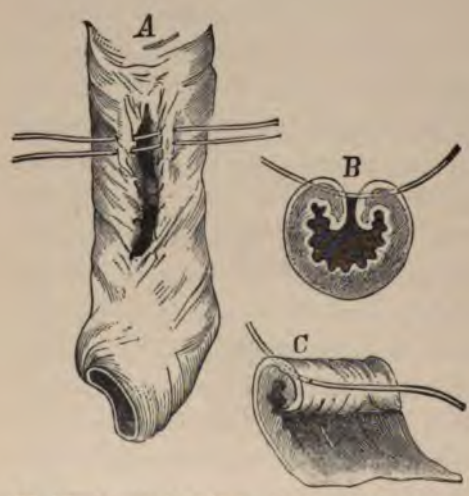

FIG. 123.—Lembert's suture. A, exterior view of suture, in place; B, transverse section; C, interior view, showing incurving of the serous coat.

FIG. 124.—Lembert's suture as applied to a transverse wound; exterior view.

wound-surfaces and the impossibility of maintaining their accurate coaptation, and by the fact that they are continually bathed by septic fæcal matter; while further they are subject to the frequent disturbances arising from peristaltic movements and to the varying distension of the gut with gas. If the adjacent serous surfaces can be brought into apposition a broader and more intimate contact is secured, and advantage is taken of the property of serous surfaces to rapidly contract between themselves close and firm adhesions by the speedy effusion of plastic lymph, which within a few hours, like a cement, agglutinates the sur-

faces apposed, covers the suture points, and fills the chinks of the irregular surfaces.

Although a wound may be fully closed within a few hours by this exudate, yet the union formed does not become firm enough to resist slight traction for several days. After the fourth day its organization into a lasting bond is more appreciable. This desired apposition of the serous surfaces of the edges of an intestinal wound is accomplished by the method of Lembert, known as "Lembert's suture" (Figures 123 and 124).

The suture is applied as follows: at a point about one-third of an inch from the edge of the wound the peritoneal coat is pierced from without inwards (Figure 124, a), the needle penetrating to the submucous coat, the fibrous tissue of which is caught in the bight of the suture; the needle is then brought out through the serous coat again (Figure 124, b) at a point equidistant from the point of entrance and the wound margin, carried across the wound, and entered on the other side (Figure 124, c), at a similar distance from the wound margin and the same manœuvre repeated in reverse order. When the loops are tied, the tension causes the edges to be inverted as a natural consequence, and the serous surfaces are held in secure apposition. The stitches should be introduced quite closely together, at intervals of from two to three-sixteenths of an inch, in order that, should distension of the bowel by gas occur before firm adhesion of the bowel has taken place, no gaping even then should be possible. It is important that the strong fibres of the submucous layer be embraced in the suture to give security to it, for a suture limited to the delicate peritoneal coat is easily torn out. The threads should not be drawn so tightly as to constrict the tissues, and cut them through, but simply firmly enough to keep the parts in apposition. The threads become imbedded in the plastic exudate that forms the new bond of union, and give no further trouble.

The choice of a material for the suture, providing it is aseptic, may be either silk or catgut. The speedy softening of catgut has been charged with exposing wounds in which it was employed to the danger of being left without support too early, but without sufficient reason, if it has been fastened in the first place with care, for so rapidly does the adhesion of the serous surfaces take place, that no danger is to be feared

from the softening of the catgut. The disasters which have taken place have been due either to lack of care in the knotting of the suture, or to sloughing of the intestinal wall. In general, however, fine sewing silk is the best material to use for making an intestinal suture; its fineness and pliability make possible the utmost delicacy of work, the knots are small, easily tied and secure, and a finer needle can be used with it than with catgut.

Ordinary round sewing needles, neither flattened nor with cutting edges, should be used for introducing the suture, in order that the wound made by the needle may be as small as possible, and free from hæmorrhage.

During the application of the suture, it is best that, if possible, the wounded part be drawn out of the abdomen, and the wound in the parietes of the abdomen kept closed as much as possible by the hands of an assistant, or better, by a sufficient number of temporary deep sutures to lessen the amount of exposure of the abdominal contents, or be packed with sponge pads. As soon as the wounded loop is brought into view, the intestine on either side of the wound is compressed by the fingers of the surgeon and of his assistant so as to prevent further access of the bowel contents to the part wounded, and by careful manipulation the bowel contents are pressed back for a distance of from two to three inches from the wound. Continued interruption of the fæcal current until the suturing is completed may be kept up by the continuance of finger pressure, or, as is usually more convenient, by thrusting a bit of rubber tubing through the mesentery at the point where pressure is desired, and after encircling the bowel with it, drawing it close enough to occlude the lumen of the bowel and holding the two parts of the tube together where they cross by an hæmostatic clamp, as seen in Figure 125. A fold of iodoform gauze may be used in the same way, or secured by knotting instead of by the clamp. Many different forms of intestinal clamps have been devised for temporary compression of the intestine, but none are superior to the simple rubber tube or gauze fillet. The fæcal current having been shut off, the wound and its neighborhood is then thoroughly cleansed by sponging and irrigation, after which the suturing is begun.

If the suture line is a long one, the suture may be applied more rapidly by making sections of continuous suture. After four or five

stitches have been taken continuously the suture should be interrupted and a knot tied. The interrupted suture has this advantage, that if one point loosens or cuts out the adjacent ones still hold, but it consumes much time to interrupt every stitch required to close a long wound. The continuous suture, on the other hand, is more quickly applied and lessens danger of gaping should the gut become distended, but if one point cuts out the adjacent ones are loosened. A judicious combination of the two methods is therefore frequently preferable.

The suture of Lembert may be preceded by a primary suture applied to the wound-edges themselves. This suture line becomes inverted into the bowel when the sero-serous suture is applied. (See Figure 126.)

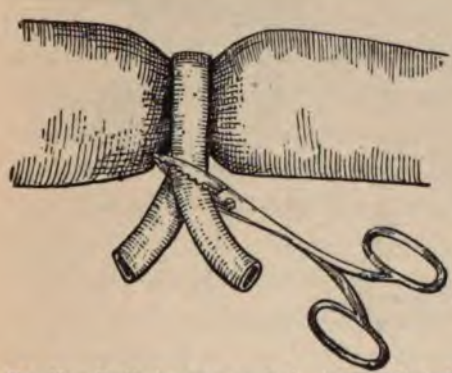

FIG. 125.—Preliminary coprostasis; lumen of intestine occluded by rubber tubing held by hæmostatic clamp.

FIG. 126.—Czerny's intestinal suture.

Such a double row of sutures is known as the suture of Czerny. By the use of two rows of sutures in this way the effectiveness and security of the suture is materially increased, but the length of time required to make it is doubled. Whenever the emergencies of the case are not such as to make great expedition imperative, this double row of sutures should be employed. A simple, rapid, and easily executed method of applying the principle of the Lembert suture in all ordinary longitudinal or transverse wounds of the intestine, and one which is quite secure and reliable, is the ordinary continuous suture (Figure 127) applied with an over-and-over stitch, catching only the serous and submucous coats, care being taken to tuck in the wound edges so as to invert them and bring a line of serous membrane into apposition as the thread is drawn tight.

FIG. 127.—The continuous intestinal suture.

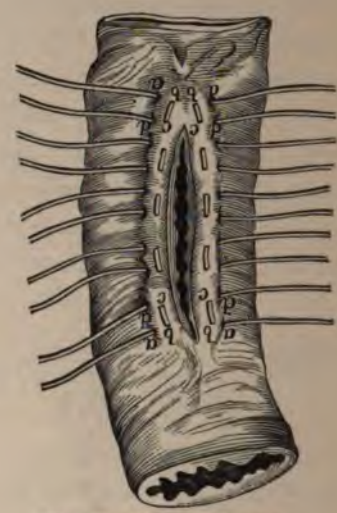

FIG. 128.—Emmert's suture.

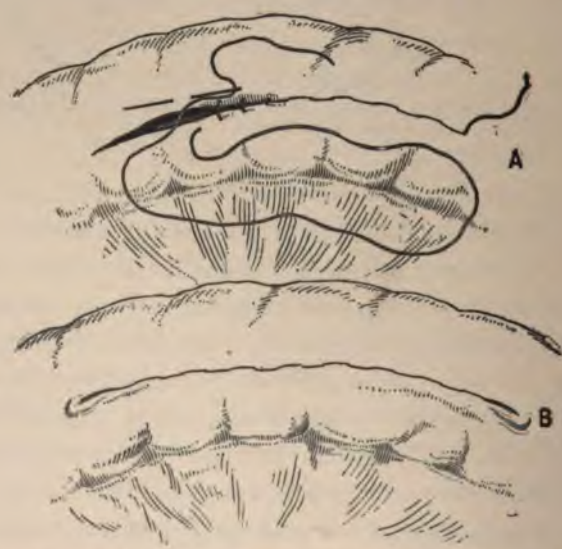

FIG. 129.—The suture of Cushing. A, the suture in course of application; B, the suture completed.

For the purpose of increasing the extent of tissue included in the loop of the suture, and thus making the suture more secure, some form of the quilt stitch may be added to the simple Lembert stitch—that known as Emmert's suture is shown in Figure 128; that of Halsted in Figure 131. In the suture of Cushing, the qualities of the quilted and the continuous suture are combined. The method of its application is shown in Figure 129. It differs from a continuous Lembert suture chiefly in that the needle is inserted parallel to the wound instead of at a right angle to it. (See Figure 129, A.) When this suture has been completed no knot or suture is visible.

Testing the Suture.—When the suturing has been completed a careful test of its adequacy to prevent escape of the intestinal contents should be made. To determine this the loop of intestine containing the suture should be allowed to become filled with the intestinal gas and liquid, and any weak or uncertain points that should develop should be reinforced by additional points of suture.

Omental Grafting.—The sutured line may be reinforced by applying over it a flap obtained from the omentum, as suggested by Senn. After the application of the suture has been finished, a flap is cut from the omentum of a length and width sufficient to cover it and a good margin beyond. This flap may be completely detached, but it is better that it be left attached by a pedicle containing a large nutrient vessel. It is fixed in its place over the line of united tissue by means of some points of suture.

The Calibre of the Intestine is a matter that should not fail to be taken into account while the apposition of the serous surfaces are being secured. Some turning-in of the intestinal edges is the necessary result of each line of suture, and by it the lumen of the canal is correspondingly diminished. The more numerous the lines of suture, the more marked the contraction of the intestinal lumen. It is in the cases of complete circular suture involving the whole circumference of the bowel that care in this respect is most frequently called for, but in cases of multiple longitudinal wounds, or in wounds with loss of substance of the bowel, it may be evident that the constriction of the lumen of the bowel that would result from the usual suture, with edges turned in, would be so great as to endanger fæcal obstruction. In such case a full

resection of the damaged section of bowel is called for, followed by circular suture, or lateral anastomosis, or implantation, as the conditions of the special case may determine. In some wounds of the large bowel it may be best not to attempt any suture or plastic effort at the time, but to secure the wound in the bowel to the wound in the abdominal wall and make an artificial anus.

The after-nutrition of the sutured intestinal territory is also to be considered in determining whether to suture the wound as it exists, or to excise more or less of the intestine as a preliminary step. No attempt should be made to suture a portion of intestine whose tissues are not perfectly sound, and the circulation in the blood-vessels of which is not active. A suture inserted in a portion of intestine that is thickened and stiffened by inflammatory exudate quickly cuts out; this also happens whenever there is any tension upon a suture. No tension whatever should be allowed to exist at any part of the suture line; when the sutured bowel has been replaced within the abdominal cavity, it should lie perfectly relaxed. If in the emergencies of a particular case it has seemed necessary to apply a suture to tissues that do not satisfy these conditions perfectly, so that a doubt exists as to the later absolute security of the suture, the opening in the abdominal wall should not be closed, but the sutured loop of intestine should be kept just within it, surrounded by suitable iodoform gauze packing to insure the escape externally of any subsequent fæcal extravasation. In most instances later spontaneous closure by granulation of a small defect in the intestine will take place, if general peritoneal infection has been guarded against. In less favorable cases subsequent plastic procedures for closing the fæcal fistula will be required.

Circular Enterorrhaphy.—The suturing together of the divided portions of an intestine, when complete division of the tube has occurred, requires further consideration. The parts to be sutured together must be brought out of the abdominal cavity and supported upon warm sponge-pads, with which also the parietal wound is packed to prevent further protrusion. Ordinary straight milliner's needles are well adapted for use in placing the stitches. They should be threaded with fine silk in lengths of about eighteen inches. Access of fæcal matter to the field of operation must be prevented by the temporary ligature (Figure

125), or by the pressure of the fingers of an assistant. For the union of the divided intestine the surgeon may rely only upon careful apposition and suturing, without the addition of any mechanical device, or may avail himself of some one of the many such devices that have been recommended. In this place I shall describe, *a*, circular suture; *b*, circular suture after invagination and exposure through a longitudinal opening in the intestine; *c*, circular suture after distension of the intestine by a mechanical device; *d*, clamping by the button of Murphy.

a. The Circular Suture.—The two ends of intestine are first secured

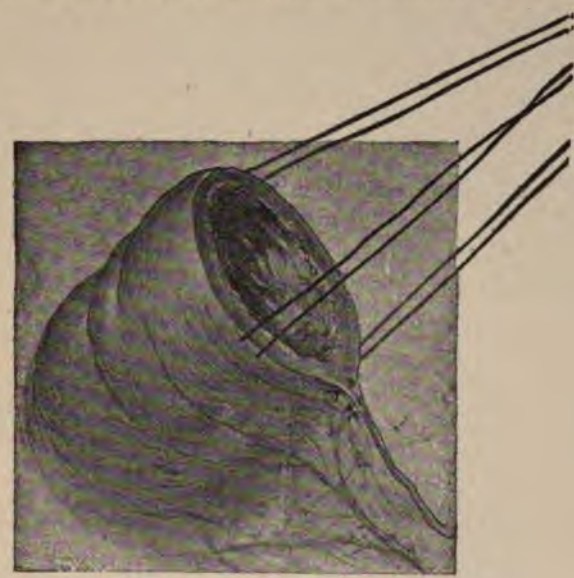

FIG. 130.—The preliminary or basting stitches (*Halsted*).

together by four preliminary or "basting" stitches, which involve all the coats. (See Figures 130 and 134.) These are cut short and turned in as the suture proper progresses, and in time fall into the cavity of the intestine. The first stitch should be applied at the mesenteric insertion; the second at the point opposite, the circumference being thus bisected; the third and fourth stitches are each to be applied on either side at a point half way between the first two. These stitches, their ends left long, serve also as the traction sutures in the method by invagination.

For the permanent sutures, the mattress sutures of Halsted, shown in Figure 131, are to be preferred, because they bring the serous surfaces

more evenly into apposition and over a larger extent than do the ordinary interrupted Lembert stitches; they tear out less easily, and but one row

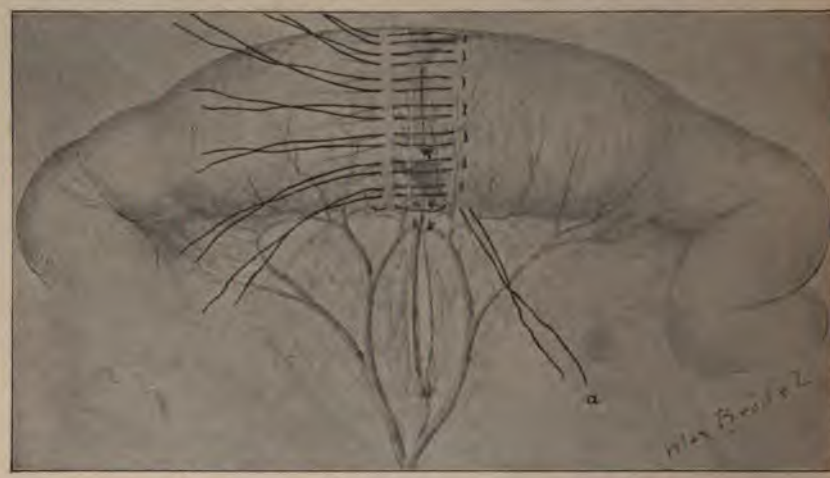

FIG. 131.—The permanent sutures applied, and ready for tying (*Halsted*).

of them is required. The first of these stitches should be applied to the mesentery at its insertion into the intestine, for it is here that imperfect

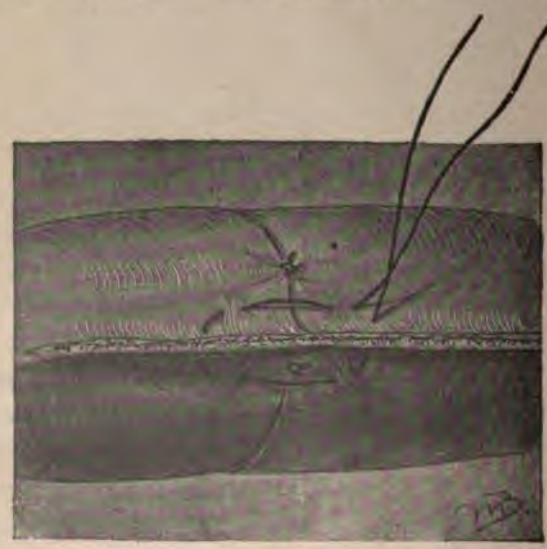

FIG. 132.—The mesenteric stitch (*Halsted*).

closure, and consequent leaking from the bowel, is most likely to occur. Figure 132 shows a method of applying this stitch which insures the

proper turning in of the mesenteric border. Starting from this point, the entire row of stitches required should be applied before any are tied, in order to prevent irregularities in the line of the suture. To lessen the danger of a stitch tearing out, care should be taken that each stitch should include some of the submucous fibres, and not be limited to the serous and muscular coats. Twelve or more of these mattress stitches suffice for the joining of the ends of the small intestine. Figure 133

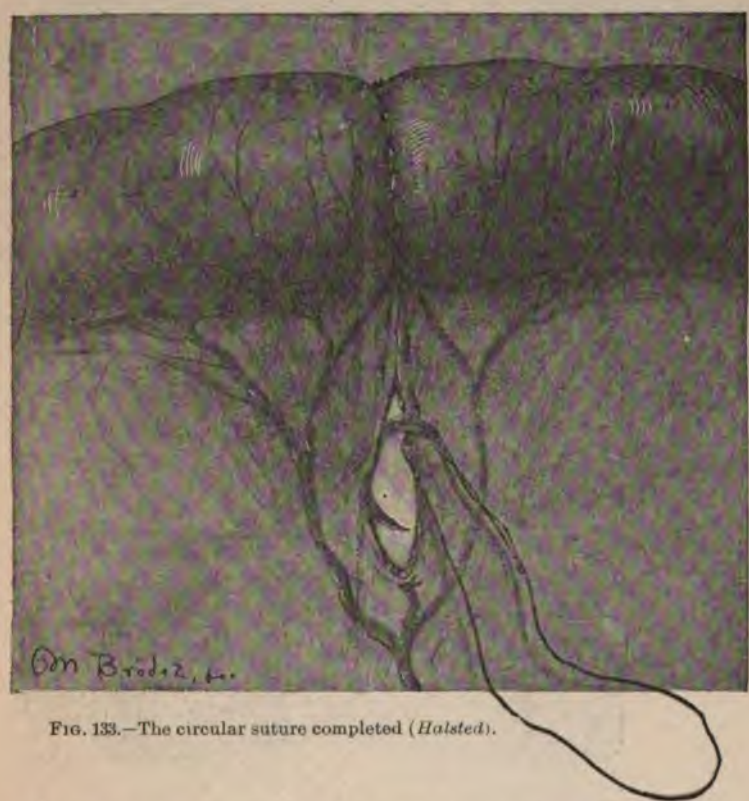

FIG. 133.—The circular suture completed (*Halsted*).

shows the suture completed, together with the suturing of the mesentery, a wedge of which has been excised. After the suture has been completed, a flap of omentum should be wrapped about it and secured to it, as described on page 415.

The Circular Suture after Invagination and Exposure through a Longitudinal Opening in the Intestine.—This is the method of Maunsell. The two ends of the intestine are first united by the four pre-

liminary stitches, as already described, the ends of which are left long, as shown in Figure 134. Especial attention should be given to the manner of applying this stitch at the mesenteric border, as shown in the cut, whereby greater security and breadth of apposition is obtained.

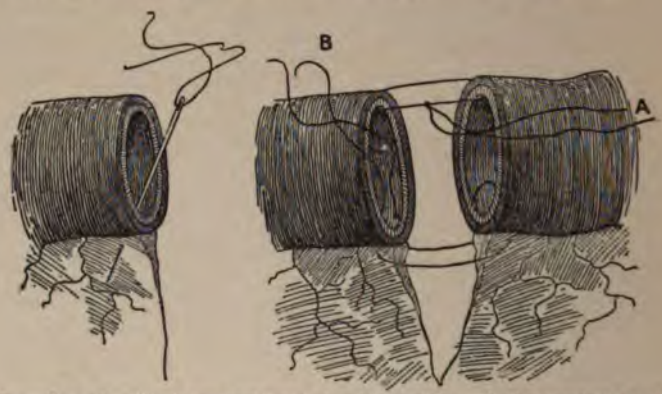

FIG. 134.—Insertion of preliminary basting or traction sutures; B, at mesenteric border; A, at summit of convex border of the bowel.

A longitudinal incision one and a half inches long is then made in the upper convex surface of either portion of the intestine, about one inch from the line of section, as shown in Figure 135.

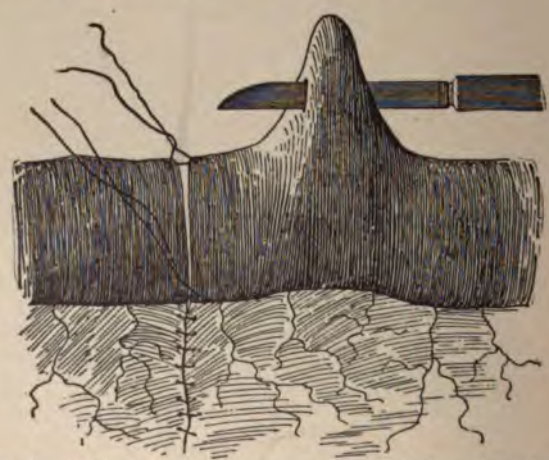

FIG 135.—Making longitudinal slit in upper convex surface of adjacent portion of intestine.

An hæmostatic clamp is then passed through this slit into the bowel and out through the interstices between the basting stitches; it seizes the long ends of these stitches in turn and draws them into the lumen of

the intestine and out above through the longitudinal slit, as shown in the diagram (Figure 136). By drawing upon these threads the cut ends of the bowel are drawn in and brought out through this slit, as shown in

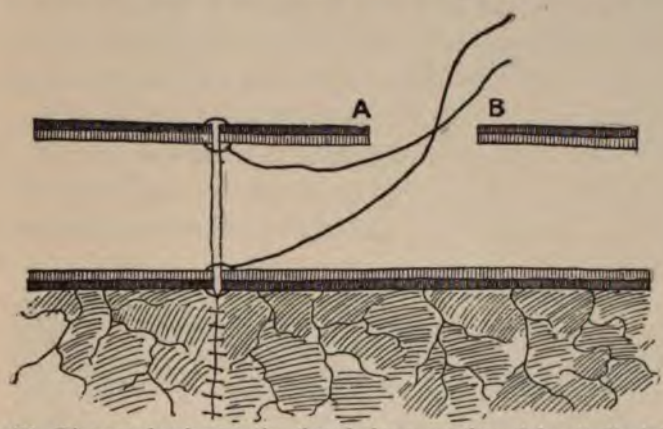

FIG. 136.—Diagram showing traction threads drawn out through longitudinal slit.

the second diagram (Figure 137). The cut bowel edges, as they protrude, have their serous surfaces broadly and perfectly in apposition, and are at once secured together by a series of sutures, each of which completely transfixes the whole thickness of the two layers of apposed bowel

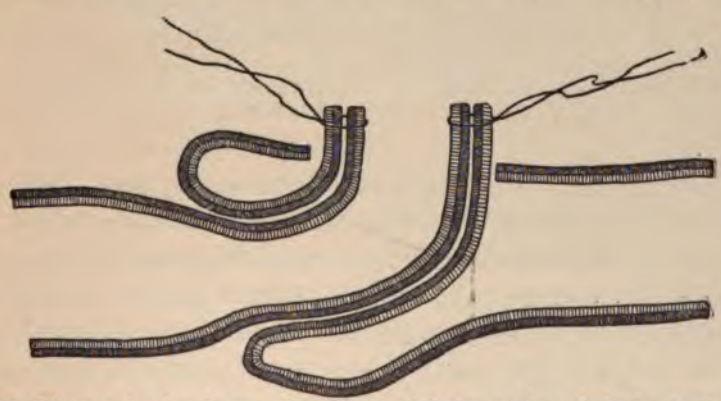

FIG. 137.—Diagram showing the cut ends of the bowel drawn out through the longitudinal slit, ready for suturing.

wall, passing through them a little less than a quarter of an inch from the cut edge. Each point of suture is tied as it is placed until the suturing has been carried all around. Upon an average, twenty points of su-

ture will be required. The long traction threads are then cut away, and the invagination reduced by pushing it back with the finger through the slit in the bowel, avoiding traction. The longitudinal slit is then closed, preferably by Cushing's suture (Figure 129), and any defect in the mesentery also sutured. The completed suture is shown in Figure 138.

By this method circular enterorrhaphy can be applied with much rapidity and with a certainty of the proper placing of the sutures. These features commend it as a method to be used by those who have had a limited previous amount of practice in such work. There is an additional longitudinal incision in the bowel to be sutured, but the doing of

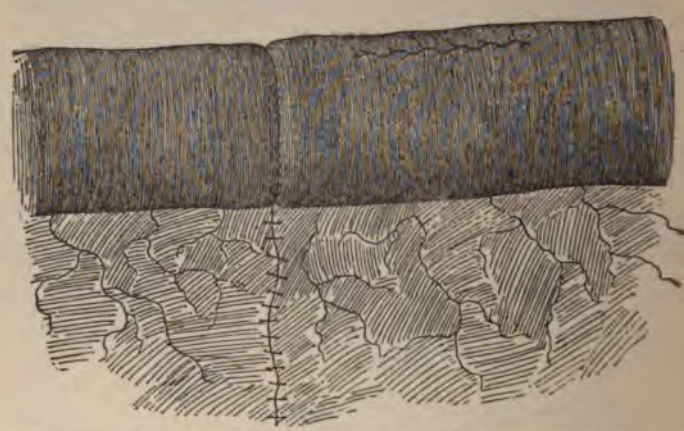

FIG. 138.—The Maunsell suture completed; the joined ends of the intestine returned to their proper position; the longitudinal slit sutured.

this presents no technical difficulties, and it is quickly done. There is a theoretical objection based upon the fact that the sutures perforate the mucous coat and may be the agents of conveying infection that will not be limited by the adhesions of the apposed peritoneal surfaces. In many reported instances in which it has been resorted to, no such misadventure has followed. Its possibility may be lessened by the use of horsehair for the sutures; by applying additional points of Lembert suture after the invagination has been reduced, and by wrapping the suture line with an omental flap.

c. Circular Suture after Distension of the Intestine by a Mechanical Device.—For the purpose of facilitating the application of the circular

suture, lessening the amount of time required, and increasing the precision of the coaptation, many different mechanical devices have been employed. Those which possess the most merit consist either of hollow cylinders, or bobbins, of absorbable material, such as raw potato (Dawbarn), candied sugar (Metcalf), decalcified bone (Robson), or of ovoid bags of rubber (Treves, Halsted, Downes) to be put in position and inflated after the ends have been secured together by the "basting" stitches, and removed after the permanent stitches have been put in place, but before they have been tied.

The raw potato, or turnip, bobbin may be taken as a type of its class, especially since it may be quickly extemporized from material readily procurable almost everywhere. One danger attends its use, and that is the possible presence of tetanus germs in the earth that clings to the surface of the vegetable, that may be transferred in the process of peeling to the bobbin, and may thence infect the raw edges of the intestine. That this is not an imaginary danger is shown by a case under the care of the writer, who died from tetanus which developed on the tenth day after enterorrhaphy over a raw potato bobbin. The bobbin, after having been carved out, should, therefore, in all cases, before being used, be immersed for a sufficient period in a reliable tetanicide solution (silver nitrate, 1:100, or tincture of iodine, full strength, or mercuric chloride, 1:1000, acidulated with acid hydrochloric 0.5 per cent.) for an hour.

The cylinder to be used may be from one and a half to two inches in length, and from one to one and a half inches in diameter, according to the calibre of the intestine into which it is to be inserted. It is transformed into a tube by removing from its centre as wide a core as is compatible with a fair degree of strength to resist moderate crushing force. Around its centre is cut a groove about three-sixteenths of an inch in width and one-eighth of an inch in depth; its two ends are rounded off, making them bluntly conical. Into the margins of each bowel end is now inserted a running draw-stitch, as follows: the needle, armed with a long thread, is inserted through all the coats of the bowel at the point farthest distant from the mesentery, at about one-eighth of an inch distance from the edge, then out again, and then, with an over-and-over stitch, as shown in Figure 139, is carried to the mesenteric attachment which is included in a return over-stitch, shown in the figure, and of

especial importance to insure the turning-in of the peritoneal surface at this critical location; thence the thread is carried up again along the other edge of the bowel to the point of beginning. One end of the cylinder is now inserted into the open end of the bowel until the groove in it is opposite the draw-stitch, which is then tied closely around it, causing the cut edge to sink down into the groove; the free end of the cylinder is then inserted into the other open bowel-end, and the draw-stitch again tied closely; the result is a uniform apposition of a fairly broad circular collar of peritoneum along the entire circumference of the bowel, which is smoothed out and held immovably in place so as to facilitate greatly the rapid and proper placing of an encircling row of Lembert or Halsted stitches. It is a practical adaptation to the act of intestine-darning of the wooden egg with which the housewife distends the toe of the stocking which she wishes to darn. The cylinder, made of absorbable material, collapses, and is swept away in the fæcal current in a time varying from a few hours to a few days, and is heard of no more. The draw-stitch falls into the bowel in due time.

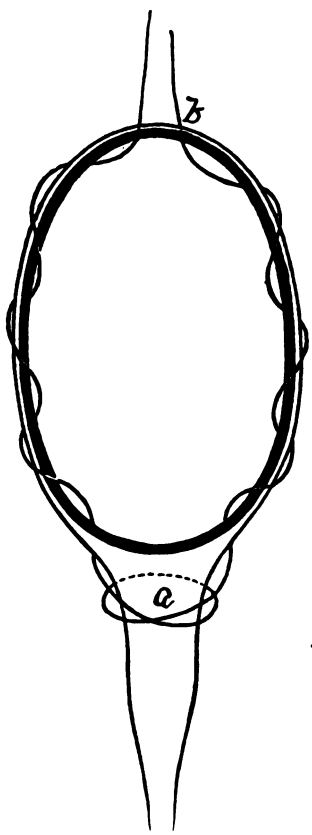

FIG. 139.—Manner of inserting running thread in end of bowel (*Murphy*).

The ovoid bags of rubber, when they are distended with air, are like small sausages, into the middle of which a small tube is inserted through which they are inflated. After the preliminary "basting" stitches (Figure 130) have been inserted, the collapsed tube is introduced into the lumen of the bowel in the space between two of these, so that one-half rests in each portion of the bowel and the small tube projects. It is then inflated, and the darning ball effect at once results. When the permanent stitches (Figure 131) have been all put in place, the air is allowed to escape, and the collapsed tube

is extracted through the space where it was put in, after which the tying of the stitches is proceeded with.

d. Clamping by the Button of Murphy.—The button of Murphy (Figure 140) is a metal bobbin, composed of two parts, which are locked together by the telescopic action of a hollow stem which projects from the centre of each part, as shown in the figure. In one half is also a movable collar which is thrust up by a coil of wire, and thus exerts a constant pressure effect upon any substance by which it is forced down. When the two parts are forced together they form a hollow cylinder, which permits fluid and semi-fluid matters to pass through. For joining the two ends of a divided bowel, each bowel-end is first furnished with a draw-stitch, as already described (Figure 139); then, the stem of one half of the button having been seized by forceps, the expanded button part is introduced into the bowel beyond the draw-stitch, which is at once tied closely down upon the stem; the other half having been secured in the other portion of the bowel (see Figure 141), the two halves are now joined by simply pushing the male half firmly down into the female.

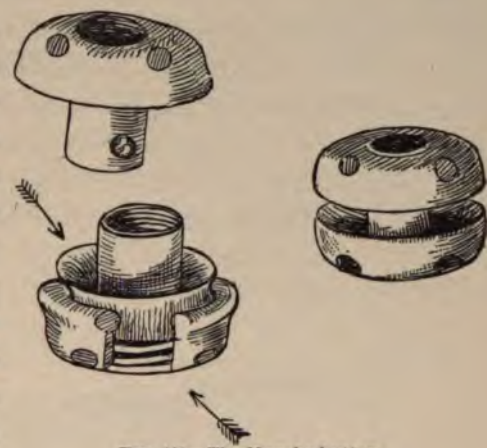

FIG. 140.—The Murphy button.

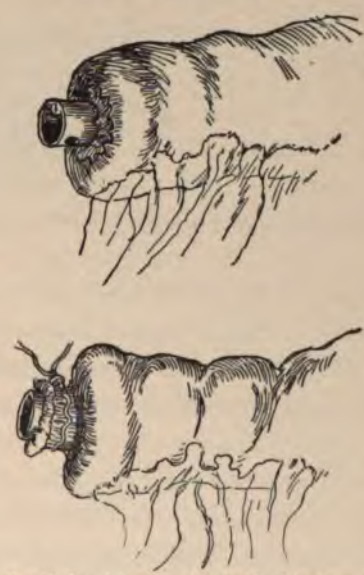

FIG. 141.—Ends of bowel with half of button secured in each; parts ready to be joined.

The mechanism locks itself. In making the junction it is important to see that no part of the mucosa protrudes, but that only the serosa is apposed in the ring of compression. Subsequently the continuous spring pressure of the movable collar upon the inturned bowel-edges gradually causes atrophy, or necrosis, until after from one to two weeks the button, as a whole, is released and floats down the intestine to be voided at the anus after a variable time. Meanwhile the apposed peritoneal surfaces outside the range of pressure have become glued together by a plastic exudate which has become organized into a permanent bond of union before the loosening of the button (Figure 142).

The junction of the ends of a divided intestine can be secured by the use of the Murphy button in much shorter time than by any other

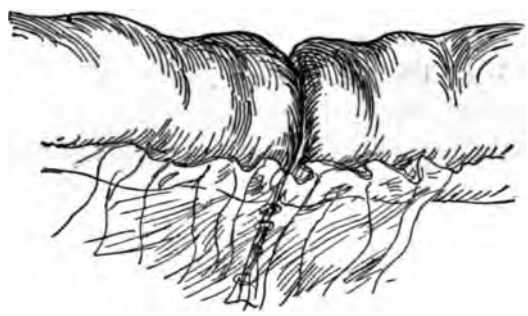

FIG. 142.—Apposition of bowel-ends secured by junction of the two parts of a Murphy button.

method, and that reliability of the union after the loosening of the button can, as a rule, be trusted has been demonstrated by abundant experience. It is a resource to be depended on especially in those cases in which the general condition of the patient is such as to make it important that the duration of operation should be as short as possible. It is of the greatest value in dealing with wounds of the small intestine. After its application, if the condition of the patient admits of prolonging the work, additional Lembert stitches may be applied to reinforce the grasp of the button.

WOUNDS OF THE KIDNEYS occur either as the result of a crushing force expended upon the loin, producing a subcutaneous laceration, or from the perforation of a gunshot missile, or from the penetration of a

sharp cutting instrument. Of these classes the subcutaneous lacerations are much the most frequently met with. Without external wound, every degree of kidney laceration may occur, with consecutive hæmorrhage and urinary extravasation. Should laceration of the overlying peritoneum also have occurred, unrestrained bleeding into the peritoneal cavity may quickly induce fatal anæmia. In the mildest degrees of kidney injury contusion and slight laceration of the cortex may alone be present, and may give rise to no symptom separable from those resulting from the contusion of the overlying soft parts. If the walls of the calyces are lacerated blood in varying quantity, as a rule, will quickly find its way through the ureter into the bladder, so that hematuria is one of the most valuable and constant evidences of subcutaneous laceration of a kidney; its absence, however, would not absolutely negative the presence of a serious kidney injury, for the ureter might be plugged by a clot, or may have been torn from its connection with the pelvis.

The lesser degrees of kidney injury call for no active surgical interference; rest, light diet, aperients, an ice-bag upon the injured loin, these satisfy the indications. In the more severe cases the primary danger to be apprehended is from hæmorrhage, the amount of which will depend on the size of the vessels lacerated. The symptoms of acute anæmia, with intraperitoneal effusion, or with a noticeable and increasing tumor in the loin following a blow over the region of a kidney, should be met at once by exploratory incision, abdominal in the first-named contingency, lumbar in the second. If the incision reveals that the main vessels have been torn, they must be ligated and the lacerated kidney taken away. If the hæmorrhage comes from the smaller vessels of the parenchyma, efforts to control it by suture and tamponade should be made; if a portion of the kidney can be saved, efforts directed to that end should be made.

In most cases the conditions that suggest exploratory incision are of gradual development, as a slowly progressive retroperitoneal accumulation of clots and urine in the injured loin occurs. A free exploratory incision is then to be made, and such ligations, total or partial resections, irrigation and drainage, done as the necessities of the case may seem to require.

A later danger that attends a perirenal hæmatoma is that of infec-

tion. The symptoms of perirenal suppuration developing at any time call for immediate incision and drainage.

An incised or stab wound of a kidney calls for enlargement of the external wound and full exposure of the wound in the viscus, followed by the adoption of the necessary means to arrest hæmorrhage and disinfect the wound. If the pelvis of the kidney have been cut, an attempt to suture the wound should be made. If either of the main blood-vessels is cut, or has to be ligated to control bleeding, the kidney should be taken away.

Gunshot wounds of a kidney may present every grade of injury from that of a graze of the renal substance, which recovers promptly under primary disinfection and drainage, to complete disorganization of the viscus, with abundant hæmorrhage, requiring early and radical interference to avert death. Frequently associated with injuries of other abdominal organs, their exposure and treatment is only a part of the total of care required. In most cases the existence of a perforating wound of the abdominal cavity calls unmistakably for exploratory abdominal incision, in the course of which the wounded kidney is exposed. If it is found much disorganized, or its pelvis widely torn, or its main vessels injured, nephrectomy should be done. In the lesser degrees of injury, after hæmostasis has been effected, a free lumbar counter-opening should be made, and drainage provided for. Post-peritoneal effusions of blood should be liberated by suitable incision and turned out as far as practicable, and gauze drainage of the cavity arranged.

Wound of a ureter, if unattended with much loss of substance, may be closed by a point of suture involving only the external coats of the tube, while a gauze pack about the area of the wound is led to the surface to insure drainage. Complete division of a ureter, or lateral loss of substance, may call for implantation into the bladder at a higher and more accessible point, implantation into some part of the bowel, extirpation of the kidney of which it is the outlet, or it may be secured in the external wound and a cutaneous ureteral fistula formed, or, finally, an anastomosis of the upper end into the lower may be effected. Most of the known instances of wound of the ureter have occurred as accidents in the course of operations on the pelvic viscera. When the lesion is deep in the pelvis, implantation into the bladder is to be done after

exposure of the parts by free abdominal incision and elevation of the pelvis. A wound in the middle or upper part of the course of a ureter may best be remedied by anastomosis of the upper end into the lower after the method of Van Hook.

Uretero-ureteral anastomosis is done as follows: The cut ends of the ureter having been exposed, the lower end is tied with a fine silk ligature close to its cut extremity; then a longitudinal slit, about one-third of an inch in length, is cut in the side of the ureter, beginning just below the ligature; the upper end is then cut obliquely, the bevel being in the posterior surface, to lessen danger of cicatricial contraction of its orifice; this upper end is then transfixed by a fine silk thread armed at both ends with a fine needle; these needles are then inserted into the slit in the distal portion of the ureter and made to perforate its wall anteriorly about an eighth of an inch below the lower angle of the slit; as the threads are drawn through they become converted into traction sutures by means of which the upper end is pulled well into the lumen of the lower end and is held there while by a series of fine silk sutures the edges of the slit and the wall of the intussuscepted end are fixed in close and secure approximation. The traction threads are then pulled out, and the joined ureter is covered in by peritoneum drawn over it and sutured. The use or not of drainage to the pelvic cavity must be determined by the general principles governing the treatment of pelvic conditions. The escape of some normal urine upon the peritoneum or into the broad ligament will not interfere with subsequent uncomplicated repair. Coexistent suppurative disease of the ureter or kidney pelvis will make the use of a drain unquestionable.

When the loss of ureter substance has been so extensive that approximation of the two ends to each other, or to the bladder, is impracticable, implantation into the bowel, extirpation of the kidney, or the formation of a cutaneous ureteral fistula remain as possible resources. The latter is to be looked upon as a temporary device, to be resorted to only when the general condition of the patient is such as to demand the abrupt conclusion of operation; implantation into the bowel presents no technical difficulties, but exposes the patient to dangers of ascending infection of ureter to kidney. Extirpation of the kidney is the preferable practice whenever the remaining kidney is sound.

WOUNDS OF THE PELVIS.

The wounds of the pelvis of which special mention must be made are those of the bladder, and those involving the rectum and anus.

WOUNDS OF THE URINARY BLADDER.—In addition to the frequent formal operative wounds made upon the bladder for the removal of stone, drainage, etc., accidental wounds from many different sources are of occasional occurrence; it is not infrequently lacerated as the result of crushing injuries of the pelvis; direct force upon a distended bladder, such as the kick of a horse, or the impact of a wagon wheel, or a fall from a height upon the abdomen, has ruptured it; a bullet traversing the pelvis, or a splinter of bone driven before such a missile may penetrate it; instances are recorded in which a portion of the bladder, having formed part of the contents of a hernial sac, the bladder has been wounded in an operation for the relief of the hernia; wounds of the bladder are occasionally sustained in the course of operations for removal of the uterus. The gravity of a bladder wound depends largely upon the presence or not of a peritoneal rent, and upon the existence or not of an external wound communicating with it through which the urine can freely escape.

Extraperitoneal rupture of the bladder occurs most frequently at the antero-superior portion of the organ, communicating with the prevesical connective tissue spaces known as the "cavity of Retzius," which region becomes infiltrated with blood and urine, and in which, as the result of early infection, suppuration and necrosis of tissue is early induced. If the rupture takes place near the neck of the bladder the infiltration is first manifest in the perineal and recto-vesical spaces, and may later reach the retropubic and anterior subperitoneal spaces.

In the treatment, if there is an external wound, it should be enlarged sufficiently to permit free escape of the urine, and prevent further urinary infiltration of adjacent spaces; if infiltration has already occurred, the infiltrated area should be freely incised; if there is no external wound, free and deep incisions should be made into all areas of infiltration by perineal or suprapubic or inguinal incisions, as the spread of the infiltration may make necessary. If the rent in the bladder is exposed by these incisions so as to permit the after ready flowing away of all escaping urine, no further interference with the bladder is called for;

any necrotic tissue already formed is cut away; a loose iodoform gauze tent is laid in the wound, and an abundant absorbent dressing is applied, to be changed as often as it becomes saturated with urine. An active granulating process is usually soon manifest, and the spontaneous closure of the bladder wound is not long delayed.

If the rent in the bladder remains deep-seated at the bottom of a tortuous channel, direct and free drainage of urine from the bladder should be provided for by a median perineal incision into the membranous portion of the urethra, through which should be passed into the bladder a good-sized soft rubber drain-tube, to be retained until the bladder wound has closed.

In cases of extensive extravasation and consequent sloughing, after the requisite incisions and removal of necrotic tissue has been done, it has been recommended to place the patient in a permanent bath, the wounds being left open, to facilitate drainage, lessen septic absorption, and stimulate granulation (Mitchell[1]).

In intraperitoneal wounds, the conditions are identical with those already discussed in connection with wounds of the hollow viscera of the abdomen, and the same method of procedure must be adopted, free external incision of the abdominal wall, suture of the rent in the viscus, and most careful cleansing of the peritoneal cavity of all extravasated matters. The well-known case reported by Walter,[2] of Pittsburg, which was the first instance in which the abdomen was opened for the purpose of treating a wound of the bladder, illustrates the value of laparotomy and cleansing of the peritoneal sac, although it is not beyond criticism, since the suture of the vesical wound was neglected, happily, however, without evil result in this instance, owing to the location of the wound in the fundus, and the continuous use of the catheter. In this case a man 22 years of age had received a blow on the hypogastric region and immediately felt a sharp pain with an urgent desire to urinate, which he could not accomplish. After some hours, the belly began to swell, the pulse became small and frequent, and the respiration rapid. A catheter brought away a minute quantity of bloody urine. Ten hours

[1] Annals of Surgery, February, 1898. p. 151.

[2] The Medical and Surgical Reporter, Philadelphia, February, 1862.

after the injury, no urine passing by the catheter, the abdomen was opened in the linea alba by a six-inch incision beginning one inch below the umbilicus and terminating one inch above the pubes. The intestines were found inflated, their peritoneal coat, as well as that lining the interior of the abdominal walls, already showing evident marks of congestion. Nearly a pint of urine and blood was removed by sponging from the pelvis, and between the convolutions of the bowels. A rent was found at the fundus of the bladder, two inches in extent. The cavity of the abdomen having been cleansed, the wound of the bladder was left to itself, as no urine was seen to escape from it, and the abdominal wound was closed. The patient awakening from the anæsthetic sleep, felt relieved of pain and the desire to urinate, so distressing before the operation; vomiting did not return; opium in one-grain doses was ordered; abstinence of drink and perfect quietude of body, with retention of the catheter, were strictly insisted upon. No unpleasant symptom followed; urine in small quantities, but free of the admixture of blood passing by the catheter. The gum-elastic catheter was replaced by a new one every two days, and was not withdrawn for two weeks after the injury had been received, and then only for a short time. Between the second and third week, the catheter was permanently withdrawn and introduced only every four hours for the evacuation of urine. After the third week, the patient left his bed. The recovery was permanent, so that he returned to his work, feeling no embarrassment in the urinary functions.

Fifteen instances in which recovery has followed abdominal section and suture of an intraperitoneal rupture of the urinary bladder were collected from literature in 1896 by Heaton.[1] Success is largely dependent upon promptitude of action. Death may be caused not only by peritonitis, but by reabsorption through the peritoneum into the blood of the excretory elements of the urine. In all cases of doubt, as well as in those in which diagnosis is reasonably certain, the abdomen should be opened without delay. Any extravasated fluid found in the peritoneal cavity should be carefully sponged out, and then the patient, having

[1] Annals of Surgery, 1896, xxiii., 676.

been put in the position of Trendelenburg (elevated pelvis), the bladder should be carefully examined by sight and touch.

The advantages offered by laparotomy in cases of wounds of the intraperitoneal portion of the bladder are thus enumerated by Vincent:[1] "With laparotomy a complete examination of the wounded region can be made, and the existence, the location, the extent, and the conformation of the solution of continuity experienced by the urinary reservoir determined; the existence and nature of complications can be seen, if a vesical artery is wounded, or any of the vascular trunks of the region have been torn, they can be ligated; if intestinal loops have been perforated, they can be sutured, with or without enterectomy; if the rectum has been perforated—a frequent event—the breach which is found can be sutured; if a splinter, from a fracture of one of the pelvic bones, projects against the bladder and is tearing it, it can be extirpated, resected, or reduced, as the case may be; if a foreign body has remained in the peritoneal cavity, it can be taken away; if the wounding agent has lodged in the walls of the bladder, or has fallen into its interior, or has become fixed in the walls of the pelvis, it may be extracted at once, which will prevent those fistulæ, those suppurations, those lithic concretions which, when they do not induce death, necessitate later, sometimes after many years of suffering, recourse to the knife, the lithotrite, or the lithotome. With laparotomy the urine can be completely removed, together with the effused blood, all the liquids and clots which may be found in the peritoneal cavity, everything which has been soiled by the urine can be disinfected; in a word, a complete antiseptic toilet of the peritoneum can be made; with laparotomy, finally, the source of urinary extravasation can be absolutely suppressed by careful suture of the bladder; a catheter retained in the bladder cannot replace the suture, this is evident."

When an intraperitoneal wound of the bladder has been suffered, the more speedily the removal of the intraperitoneal extravasations by laparotomy, and the closure of the wound by suture, is effected, the greater will be the probabilities of a successful issue. Though it should have

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[1] *Plaies pénétrantes intrapéritonéales de la vessie. Revue de Chirurgie*, 1881, i., p. 572.

been delayed until severe inflammatory and septic conditions have already developed, the incision of the abdominal wall, the removal of effusions already present, free irrigations and adequate drainage, may still afford a possibility of recovery from what would otherwise pursue an inevitably fatal course.

Suture of the Bladder.—Caution and thoroughness in applying the suture to a bladder-wound is especially requisite. The suturing must extend well beyond the limits of the rent at each end. Fine silk should be used for the suture. If the conditions are favorable, a double row of sutures are desirable, one at the edges of the wound, but excluding the mucous coat, and another row which pierces the serous coat a little distance from the edges of the wound, by which a more extensive turning in and apposition of the serous membrane is accomplished.

Each line of suture should be applied as a continuous suture, on account of the greater certainty, ease, and speed with which it can be applied to a deep-seated part like the bladder.

The number of cases has already become considerable in which suture of the bladder has been done, with recovery, in cases of wounds of the bladder inflicted by surgeons during the removal of pelvic and abdominal neoplasms.

Continuous Catheterization.—Free and uninterrupted drainage of the bladder by continuous retention of a catheter in the bladder through the urethra should be maintained for a week or ten days after the injury. The catheter should be soft and flexible, open at the end, and its end should reach just within the vesical orifice. It should be removed, washed, and returned once daily during the period of retention. For some time, a week or more, after its continuous residence in the bladder is dispensed with, it should yet be used several times daily to remove the urine, during which time no effort to urinate should be made by the unaided contraction of the bladder.

Wounds of Anus and Rectum.—Wounds involving the lower end of the alimentary canal must be treated as open wounds. In order to preserve them from sepsis it is necessary that the wound cavity be kept packed with energetically antiseptic absorbent material and that the function of defæcation be kept in abeyance. The lower bowel should be thoroughly washed out with a boric acid solution, and the movements of

the bowels checked by opium. The wound itself should be freely irrigated with an eight per cent. solution of chloride of zinc, after which iodoform gauze should be lightly packed into the wound so as to reach every recess. This should be covered in by a plentiful layer of absorbent gauze, the whole kept in position by a T-bandage. Whenever a movement of the bowels becomes necessary, sufficient of the dressings must be removed to permit the issue of the fæcal matter, after which the bowel should be cleansed and the wound redressed as at first. When the wound has become a superficial granulating surface, the rigid antiseptic efforts may be relaxed and the sore be kept smeared simply with boracic ointment.

CHAPTER XXII.

WOUNDS OF THE EXTREMITIES—AMPUTATION.

Limitations of Conservation*—Classification of Wounds possibly demanding Amputation—Duty in Doubtful Cases—*Period for Amputation*—Primary, Intermediary, and Secondary Periods defined—Effect of Antiseptics to prolong Primary Period—Shock a Contra-indication—Amputation to be done during Primary Period—*Point of Amputation—Treatment of the Amputation Wound.

THERE remain for presentation some considerations as to the management of lacerated, contused, or gunshot wounds of the extremities in which the damage is so extensive as to compromise the vitality of the parts beyond the wound and to cause the question of amputation to be entertained. Interest centres about three points, viz.:—To what extent should attempts at conservation be pushed, and, if amputation is imperative, when and at what point should it be done?

LIMITATIONS OF CONSERVATION.—In deciding to what extent attempts at conservation should be pushed, two considerations must influence the surgeon. These are: 1. Can the vitality of the distal portions of the limb be preserved? and, 2. If preserved, will the limb be a useful member or a useless incumbrance?

For purposes of systematic consideration the wounds in question may be divided into five general classes, as follows:

1. Injuries in which the whole mass of the limb, to a variable distance from its end, is mangled and pulpified, or torn nearly away.

2. Injuries in which, at a limited part of the continuity of a limb, all the tissues in its whole thickness have been crushed.

3. Injuries of less extent but in which the great vessels of an extremity have been lacerated.

4. Injuries characterized by open wounds communicating with extensively comminuted bones or with large joint cavities.

5. Injuries characterized by extensive stripping away of soft parts, as integument and muscles.

In the two first of these classes the duty of the surgeon is plain; primary amputation must be performed; but amputation in these cases is to be regarded less as a formal operation than as a part of the general procedure of the primary cleansing of the wound, which requires that devitalized tissues shall be removed as perfectly and speedily as possible from every wound.

In the remaining three groups, the propriety of attempts at conservation must depend on the facilities at the command of the surgeon for preserving the wound from septic infection and securing to it perfect rest during repair, and upon the probable future usefulness of the part, if amputation is avoided. The mere wound of the great vessels, unless it be attended with such extensive laceration of the adjacent soft parts as to render the nutrition of the distal portion of the limb by the collateral circulation obviously improbable, does not call for immediate amputation. Wounds of the joint cavities and compound comminuted fractures, in the great majority of cases, can be conducted to recovery by adequate measures of disinfection, drainage, and immobilization. The extensive stripping away of soft parts, although ultimate cicatrization of the wound may be possible, may nevertheless be a sufficient cause in some cases for primary amputation, on account of the deformity or uselessness of the part which would be left.

Cases will present themselves in which the question, whether the vitality of the distal portions of the limb can be preserved or not, must be a doubtful one, and will depend on the prevention of inflammatory disturbances in the wound, and in placing the endangered portion of the limb in conditions that shall favor its nutrition as perfectly as possible. It would be incumbent on the surgeon, in such a case, to make the effort at conservation, and to resort to amputation only when it had become plain that the efforts at protection were unsuccessful, or that the vitality of the endangered tissues was hopelessly destroyed.

Period for Amputation.—Wounds in which the accession of septic conditions is not prevented have their history divided into three periods, *primary, intermediary,* and *secondary,* the primary being that short period which intervenes between the reception of the wound and the appearance of the secondary traumatic fever caused by the development of septic inflammation in the wound, a period generally of from thirty-six

to forty-eight hours; the intermediary period being the period during which progressive local inflammatory infiltration and general fever prevail, a period extending over a variable time; the secondary beginning with the subsidence of the intermediary stage, as marked by limitation and diminution of the infiltration and free suppuration from the wound surfaces.

When adequate antiseptic measures are employed, the primary stage is indefinitely prolonged, inflammatory infiltration and secondary traumatic fever are prevented, and an opportunity afforded for the full display of the reparative resources of the injured part.

When the necessity of amputation is unquestionable, it should, if possible, be done before the supervention of the intermediary stage. If this has been impracticable, it should be deferred to the secondary period, unless progressive gangrene of the wound develop, when amputation, through tissues yet sound, should be done as quickly as possible. Amputation should never be done, in any case, until full reaction from the shock of the original injury has been secured, and, if such reaction is delayed until the primary stage has passed, the operation must be deferred yet longer, until the secondary stage has been reached.

The prolongation of the primary stage by antiseptic treatment—continuous antiseptic irrigation being the method which, in general, is best adapted to the treatment of these cases—makes it possible for the surgeon to delay amputation until such time as, in his judgment, the patient will be in the best condition to bear the operation. In some cases it will happily have served to demonstrate the possibility of recovery without amputation. In cases, the possibility of saving which manifestly depends entirely upon the success of the efforts to prevent their being invaded by septic infection, as soon as it is evident that these efforts have not been successful, amputation should be proceeded with before the full local and constitutional symptoms of the sepsis have developed.

Point of Amputation.—The choice of the point at which the amputation shall be made may be greatly influenced by the facilities at the command of the surgeon for keeping the wound aseptic. If these be adequate for the purpose, the section may be made at whatever point may be desirable to give the patient the most useful stump, even though bruised and lacerated parts be included in the flaps. These are preserved

from inflammatory disturbance, their full vitality is regained, and they participate in the formation of the stump without disaster from sloughing. When, for any reason, the wound cannot receive adequate antiseptic treatment, amputation will, if possible, be made at a point sufficiently far above the injury to exclude all bruised and lacerated tissue from the flaps.

TREATMENT OF THE AMPUTATION-WOUND.—In the treatment of the wounds made by amputation, scrupulous attention should be paid to all the details of treatment which have been dwelt upon in the chapters on the "Practice of Wound-Treatment" in the first part of this work. Absolute aseptic cleanliness of everything—hands, instruments, dressings, —that is brought in contact with the wound; perfect arrest of hæmorrhage by catgut, cut short after being securely knotted; ample provision for drainage from the deepest recesses of the wound; thorough disinfection of the wound surfaces; careful apposition of the flaps by both deep and superficial sutures; protection, support, and compression by external antiseptic dressings; an elevated and comfortable position for the stump and protection of the limb from motion or external traumatism of any kind, these constitute the indications to be observed. The various means by which they may be met have been sufficiently pointed out. The adaptation of the particular agents to each special case must be left to the judgment of the surgeon.

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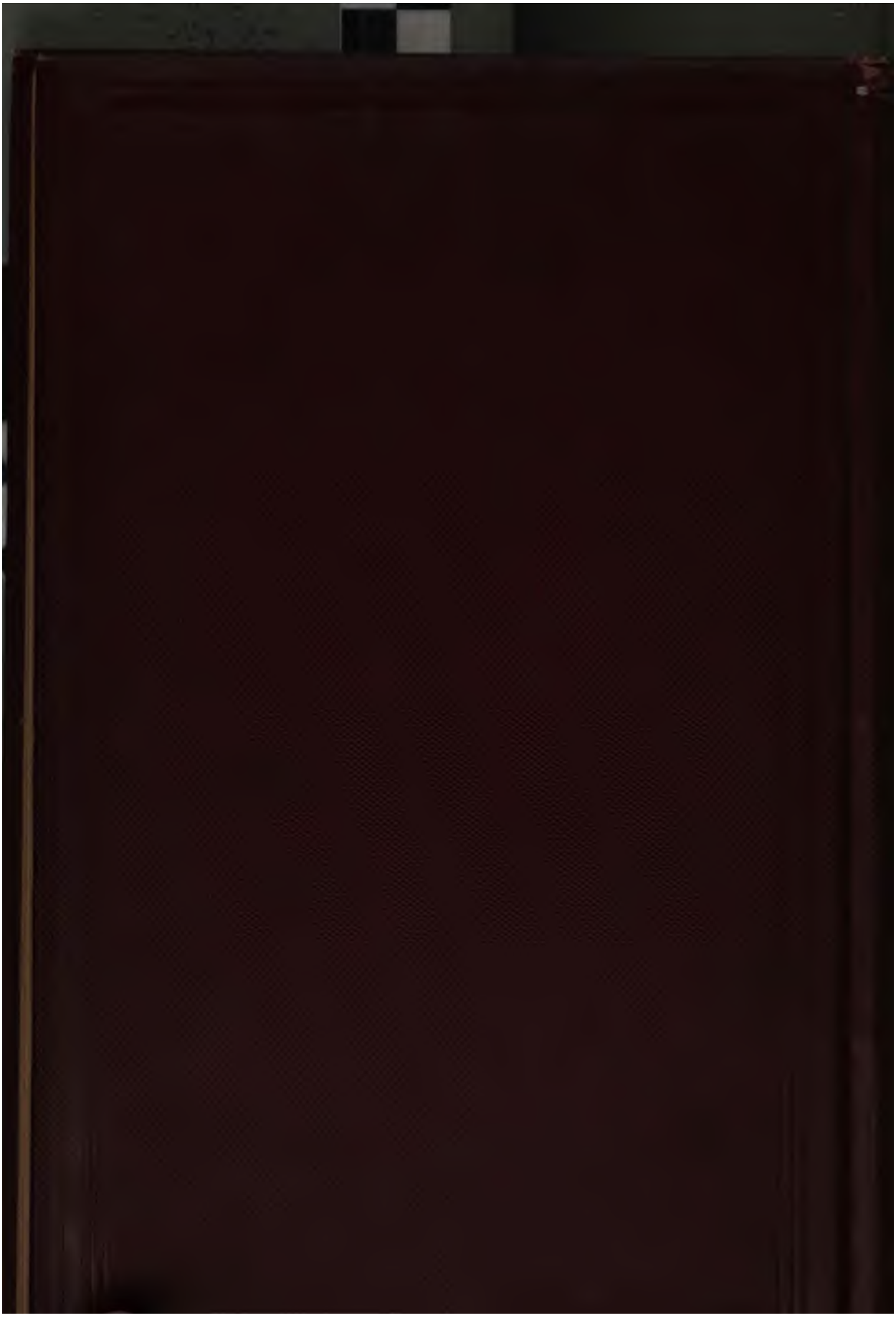
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